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(57) Abstract

Novel packaging cell lines useful for generating viral accessory protein independent HIV-derived retroviral vector particles, methods of constructing such packaging cell lines and methods of using the viral accessory protein independent HIV-derived retroviral vector particles are disclosed.

(57) Abrégé

L'invention concerne de nouvelles lignées de cellules d'encapsidation utiles pour produire des particules de vecteur rétroviral dérivé du VIH indépendantes de protéines accessoires virales, des procédés de mise au point de ces lignées de cellules d'encapsidation et des procédés d'utilisation des particules de vecteur rétroviral dérivé du VIH indépendantes de protéines accessoires virales.

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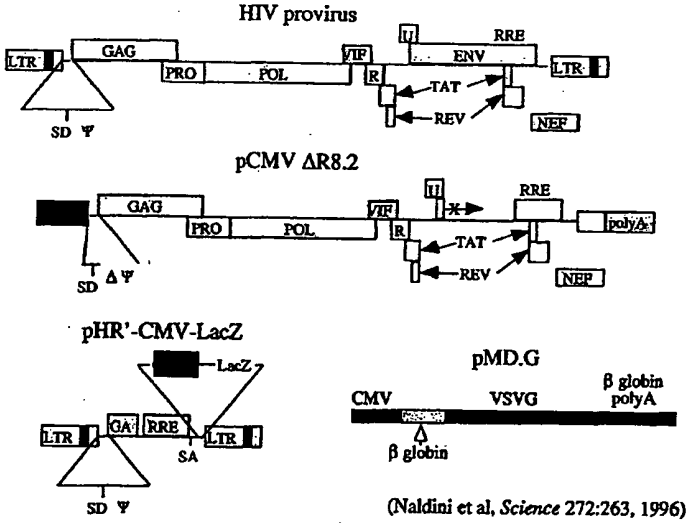

(Naldini et al, *Science* 272:263, 1996)

(57) Abstract

Novel packaging cell lines useful for generating viral accessory protein independent HIV-derived retroviral vector particles, methods of constructing such packaging cell lines and methods of using the viral accessory protein independent HIV-derived retroviral vector particles are disclosed.

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Description

PACKAGING CELL LINES FOR HIV-DERIVED RETROVIRAL VECTOR PARTICLES

BACKGROUND OF THE INVENTION

Retroviral vectors based on lentiviruses, such as human immunodeficiency viruses (HIV), can infect nondividing cells, and integration of proviral DNA occurs without the need for cell division. These properties make lentiviruses attractive for gene transfer into nondividing cells, such as hepatocytes, myofibers, hematopoietic stem cells, and neurons.

However, the use of lentivirus vectors, particularly HIV vectors, particularly for gene therapy, is hampered by concern over their safety. Thus, a need for the development of lentivirus vectors, particularly HIV vectors, with improved safety, particularly for gene therapy, exists.

SUMMARY OF THE INVENTION

The present invention relates to novel packaging cell lines useful for generating viral accessory protein independent lentivirus-derived, particularly HIV-derived, retroviral vector particles, to construction of such cell lines and to methods of using the accessory protein independent lentivirus-derived retroviral vector particles to introduce DNA of interest into cells (e.g, eukaryotic cells such as animal (particularly mammalian), plant or yeast cells or prokaryotic cells such as bacterial cells). In a preferred embodiment, the packaging cell lines of the present invention are stable packaging cell lines.

In one embodiment of the invention, packaging cell lines for producing a viral accessory protein independent lentivirus-derived retroviral vector particles comprise (a) a cell (e.g., mammalian cell); and (b) a retroviral nucleotide sequence in the cell which comprises a coding sequence for lentivirus *gagpol*, wherein said coding sequence has

been codon optimized by mutagenisis to improve expression of the lentivirus gagpol proteins.

In second embodiment of the invention, packaging cell lines for producing a viral accessory protein independent lentivirus-derived retroviral vector particles comprise (a) a cell (e.g., mammalian cell); (b) a first retroviral nucleotide sequence in the cell which comprises a coding sequence for lentivirus *gagpol*, wherein said coding sequence has been codon optimized by mutagenisis to improve expression of the lentivirus gagpol proteins; and (c) a second retroviral nucleotide sequence in the cell which comprises the coding sequence for a heterologous envelope protein.

In a third embodiment of the invention, packaging cell lines for producing a viral accessory protein independent lentivirus-derived retroviral vector particles comprise (a) a cell (e.g., mammalian cell); (b) a first retroviral nucleotide sequence in the cell which comprises a coding sequence for lentivirus *gagpol*, wherein said coding sequence has been codon optimized by mutagenisis to improve expression of the lentivirus gagpol proteins; (c) a second retroviral nucleotide sequence in the cell which comprises the coding sequence for a heterologous envelope protein; and (d) a third retroviral nucleotide sequence which comprises a DNA sequence of interest and lentivirus cis-acting sequences required for packaging, reverse transcription and integration.

In a fourth embodiment of the invention, packaging cell lines for producing a viral accessory protein independent lentivirus-derived retroviral vector particles comprise (a) a cell (e.g., mammalian cell); (b) a retroviral nucleotide sequence in the cell which comprises a coding sequence for lentivirus *gagpol*, wherein said coding sequence has been codon optimized by mutagenisis to improve expression of the lentivirus gagpol proteins; and (c) a retroviral nucleotide sequence which comprises a DNA sequence of interest and lentivirus cis-acting sequences required for packaging, reverse transcription and integration.

In a fifth embodiment of the invention, packaging cell lines for producing a viral accessory protein independent HIV-derived retroviral vector particles comprise (a) a cell

(e.g., mammalian cell); and (b) a retroviral nucleotide sequence in the cell which comprises a coding sequence for HIV *gagpol*, wherein said coding sequence has been codon optimized by mutagenisis to improve expression of the HIV gagpol proteins.

In sixth embodiment of the invention, packaging cell lines for producing a viral accessory protein independent HIV-derived retroviral vector particles comprise (a) a cell (e.g., mammalian cell); (b) a first retroviral nucleotide sequence in the cell which comprises a coding sequence for HIV *gagpol*, wherein said coding sequence has been codon optimized by mutagenisis to improve expression of the HIV gagpol proteins; and (c) a second retroviral nucleotide sequence in the cell which comprises the coding sequence for a heterologous envelope protein.

In a seventh embodiment of the invention, packaging cell lines for producing a viral accessory protein independent HIV-derived retroviral vector particles comprise (a) a cell (e.g., mammalian cell); (b) a first retroviral nucleotide sequence in the cell which comprises a coding sequence for HIV *gagpol*, wherein said coding sequence has been codon optimized by mutagenisis to improve expression of the HIV gagpol proteins; (c) a second retroviral nucleotide sequence in the cell which comprises the coding sequence for a heterologous envelope protein; and (d) a third retroviral nucleotide sequence which comprises a DNA sequence of interest and HIV cis-acting sequences required for packaging, reverse transcription and integration.

In a eighth embodiment of the invention, packaging cell lines for producing a viral accessory protein independent HIV-derived retroviral vector particles comprise (a) a cell (e.g., mammalian cell); (b) a retroviral nucleotide sequence in the cell which comprises a coding sequence for HIV *gagpol*, wherein said coding sequence has been codon optimized by mutagenisis to improve expression of the HIV gagpol proteins; and (c) a retroviral nucleotide sequence which comprises a DNA sequence of interest and HIV cis-acting sequences required for packaging, reverse transcription and integration.

Alternatively, each of the packaging cell lines described herein can be produced using (1) a retroviral nucleotide sequence which comprises a codon optimized gag

coding sequence and (2) a retroviral nucleotide sequence which comprises a codon optimized pol coding sequence, in place of the retroviral nucleotide sequence which comprises a codon optimized gagpol coding sequence.

In a particular embodiment, the heterologous envelope protein is the G glycoprotein of vesicular stomatitis virus (VSV G). In another embodiment, the heterologous envelope protein is the amphotropic envelope of the Moloney leukemia virus (MLV).

Cell lines for producing a viral accessory protein independent lentivirus-derived retroviral vector particles are produced by transfecting host cells (e.g., mammalian host cells) with a plasmid comprising a DNA sequence which encodes lentivirus *gagpol* proteins, wherein said DNA sequence has been codon optimized by mutagenisis to improve expression of the lentivirus gagpol proteins. Depending upon the particular cell line being produced, the host cells are also co-transfected with a plasmid comprising a DNA sequence which encodes a heterologous envelope protein, or a plasmid comprising a DNA sequence of interest and lentivirus cis-acting sequences required for packaging, reverse transcription and integration, or both of these plasmids. Alternatively, host cells are transfected with a plasmid comprising a codon optimized DNA sequence encoding a lentivirus gag protein and a plasmid comprising a codon optimized DNA sequence encoding a lentivirus pol protein, in place of the plasmid comprising a codon optimized DNA sequence encoding both lentivirus gagpol proteins.

Cell lines for producing a viral accessory protein independent HIV-derived retroviral vector particles are produced by co-transfecting host cells (e.g., mammalian host cells) with a plasmid comprising a DNA sequence which encodes HIV *gagpol* proteins, wherein said DNA sequence has been codon optimized by mutagenisis to improve expression of the HIV gagpol proteins. Depending upon the particular cell line being produced, the host cells are also co-transfected with a plasmid comprising a DNA sequence which encodes a heterologous envelope protein, or a plasmid comprising a DNA sequence of interest and HIV cis-acting sequences required for packaging, reverse

transcription and integration, or both of these plasmids. Alternatively, host cells are transfected with a plasmid comprising a codon optimized DNA sequence encoding a HIV gag protein and a plasmid comprising a codon optimized DNA sequence encoding a HIV pol protein, in place of the plasmid comprising a codon optimized DNA sequence encoding both HIV gagpol proteins.

The present invention also relates to methods of producing viral accessory protein independent lentivirus-derived retroviral vector particles, comprising co-transfecting host cells (e.g., mammalian host cells) with (a) a first plasmid comprising a DNA sequence which encodes lentivirus *gagpol* proteins, wherein said DNA sequence has been codon optimized by mutagenisis to improve expression of the lentivirus gagpol proteins; (b) a second plasmid comprising a DNA sequence which encodes a heterologous envelope protein; and (c) a third plasmid comprising a DNA sequence of interest and lentivirus cis-acting sequences required for packaging, reverse transcription and integration. Alternatively, host cells are transfected with a plasmid comprising a codon optimized DNA sequence encoding a lentivirus gag protein and a plasmid comprising a codon optimized DNA sequence encoding a lentivirus pol protein, in place of the first plasmid comprising a codon optimized DNA sequence encoding both lentivirus gagpol proteins.

In a particular embodiment, the invention relates to methods of producing viral accessory protein independent HIV-derived retroviral vector particles, comprising co-transfecting host cells (e.g., mammalian host cells) with (a) a first plasmid comprising a DNA sequence which encodes HIV *gagpol* proteins, wherein said DNA sequence has been codon optimized by mutagenisis to improve expression of the HIV gagpol proteins; (b) a second plasmid comprising a DNA sequence which encodes a heterologous envelope protein; and (c) a third plasmid comprising a DNA sequence of interest and HIV cis-acting sequences required for packaging, reverse transcription and integration. Alternatively, host cells are transfected with a plasmid comprising a codon optimized DNA sequence encoding a HIV gag protein and a plasmid comprising a

codon optimized DNA sequence encoding a HIV pol protein, in place of the first plasmid comprising a codon optimized DNA sequence encoding both HIV gagpol proteins.

The present invention also relates to viral accessory protein-independent retroviral particles produced by or obtainable by (obtained by) the methods described herein.

The present invention further relates to isolated DNA encoding a codon optimized lentivirus *gagpol*, isolated DNA encoding the *gag* coding region of a codon optimized lentivirus *gagpol*, and isolated DNA encoding the *pol* coding region of a codon optimized lentivirus *gagpol*. In a particular embodiment, the present invention relates to isolated DNA encoding a codon optimized HIV *gagpol*, isolated DNA encoding the *gag* coding region of a codon optimized HIV *gagpol*, and isolated DNA encoding the *pol* coding region of a codon optimized HIV *gagpol*.

The packaging cell lines and viral particles of the present invention can be used for gene therapy or gene replacement with improved safety. The packaging cell lines and viral particles of the present invention can also be used in development and production of vaccines, and in production of biochemical reagents. Gene therapy vectors produced with the cell lines of the present invention are expected to be valuable medical therapeutics.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram of an expression cassette containing the codon optimized *gagpol* genes. The DNA was constructed in multiple segments, which are indicated at the top as 1/3, 2/3, 3/3 (A, B, C and D) and HIN. Restriction sites used to assemble the cloned segments are indicated above the kilobasepair (Kb) ruler. Below the ruler are multiple features showing the location of the human cytomegalovirus (CMV) promoter, human betaglobin sequences (Bglobin), mRNA sequences (thinner line represents intronic sequence), the *gag* and *pol* open reading frames, the individual

proteolytic fragment coding sequences (p17_MA, p24_CA, p7, p6, PR, p51_RT, RNaseH and integrase (IN)) and each synthetic oligonucleotide used in the assembly process (multiple adjacent open arrows).

Figure 2 is a table which depicts codon usage frequencies in genes which are highly expressed and in the codon optimized gagpol open reading frame of the HIV packaging construct described herein.

Figure 3 is a schematic representation of the HIV provirus and a three-plasmid expression system used for generating a pseudotyped HIV-based vector by transient transfection as described in Naldini *et al.*, *Science, 272*:263-267 (1996).

Figure 4 is a list of some characteristics relating to the HIV Rev protein.

Figure 5 is a list of some points relating to codon optimization of HIV *gagpol*.

Figure 6 is a partial DNA sequence of HIV *gag* (SEQ ID NO: 1), showing inactivation of inhibitory sequences as described in Schwartz, S. *et al.*, *J. Virol.*, *66*(12):7176-7182 (1992).

Figure 7 a plot of the %(G+C) content of wildtype HIV *gagpol* sequences and theoretically codon optimized HIV *gagpol* sequences. The percent of bases, either G or C, was calculated for a 30 nucleotide moving window for the entire length of the *gagpol* gene, and the value plotted versus nucleotide position. Diamonds = HIV *gagpol* sequences; squares = full optimal back-translation for *gag* open reading frame; triangles = full optimal back-translation for *pol* open reading frame; CO = codon optimized.

Figures 8A-8E depict the alignment of the nucleotide sequences and predicted amino acid sequences for the *gag* coding region of a wildtype HIV *gagpol* and a codon optimized HIV *gagpol*. "NL4-3 genbank.SEQ" indicates the nucleotide sequence (SEQ ID NO:2) and predicted amino acid sequence (SEQ ID NO:3) for the *gag* coding region of a wildtype HIV *gagpol*. "pHDMHgpm2.seq" indicates the nucleotide sequence (SEQ ID NO:4) and predicted amino acid sequence (SEQ ID NO:5) for the *gag* coding region

of a codon optimized HIV *gagpol*. The "NL4-3 genbank.SEQ" sequences are publicly available at the NIH GenBank sequence repository (Accesssion No. M19921).

Figures 9A-9L depict the alignment of the nucleotide sequences and predicted amino acid sequences for the *pol* coding region of a wildtype HIV *gagpol* and a codon optimized HIV *gagpol*. "NL4-3 genbank.SEQ" indicates a nucleotide sequence (SEQ ID NO:6) and a predicted amino acid sequence (SEQ ID NO:7) for the *pol* coding region of a wildtype HIV *gagpol* available in the NIH GenBank sequence repository (Accesssion No. M19921). The nucleotide and amino acid sequences for the *pol* coding region available in the GenBank sequence repository contain two sequence errors, which are indicated in Figures 9A-9L with shading. "pNL4-3.seq" indicates the correct nucleotide sequence (SEQ ID NO:8) and predicted amino acid sequence (SEQ ID NO:9) for the *pol* coding region of a wildtype HIV *gagpol*. "pHDMHgpm2.seq" indicates the nucleotide sequence (SEQ ID NO:10) and predicted amino acid sequence (SEQ ID NO:11) for the *pol* coding region of a codon optimized HIV *gagpol*.

Figures 10A-10D depict the DNA sequence (SEQ ID NO:12) for pHDMHgpm2. The CMV enhancer/promoter is at nucleotides 97 to 679, human betaglobin sequences (Bglobin) are at nucleotides 761 to 864, 865 to 1303 and 5710 to 6469 (end of Bglobin is at nucleotdes 6445 to 6469), mRNA sequences are at nucleotides 680 to 778 and 1255 to 5921, SV40 origin of replication is at nucleotides 8796 to 8908, beta-lactamase (bla) coding region is at nucleotides 6709 to 7569, intron sequences are at nucleotides 779 to 1254, the codon optimized *gag* coding region is at nucleotides 1318 to 2820, the codon optimized *pol* coding region is at nucleotides 2619 to 5624 and the poly A site is at nucleotides 5897 to 5921.

Figure 11 is a circular map of plasmid pHDMHgpm2.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to novel packaging cell lines useful for generating viral accessory protein independent lentivirus-derived, particularly HIV-derived,

retroviral vector particles, to construction of such cell lines and to methods of using the accessory protein independent lentivirus-derived retroviral vector particles to introduce DNA of interest into cells (e.g, eukaryotic cells such as animal (particularly mammalian), plant or yeast cells or prokaryotic cells such as bacterial cells). In a particular embodiment, the packaging cell lines of the present invention are stable packaging cell lines.

The cell lines are engineered to express the lentivirus proteins necessary for virus particle formation (gagpol proteins), without containing DNA sequences from lentivirus accessory proteins (tat, vif, vpr, vpu, nef and rev proteins and Rev response element (RRE)). Additionally, no viral sequences (such as cis-acting elements termed constitutive transport elements (CTEs)) will be expressed as RNA of any kind. DNA sequences for lentivirus *gagpol* are codon optimized by extensively mutagenizing the sequences to improve expression and to reduce the risk of recombination between transfer vector sequences and gagpol messenger RNA. This greatly improves the safety of virus preparations generated from these cell lines. In a particular embodiment, the DNA sequences for lentivirus *gagpol* are not codon optimized in the overlap region between the *gag* and *pol* sequences and in cis-acting signals necessary for translation of pol.

Examples of lentiviruses include human immunodeficiency viruses (e.g., HIV-1, HIV-2, HIV-3), bovine lentiviruses (e.g., bovine immunodeficiency viruses, bovine immunodeficiency-like viruses, Jembrana disease viruses), equine lentiviruses (e.g., equine infectious anemia viruses), feline lentiviruses (e.g., feline immunodeficiency viruses, panther lentiviruses, puma lentiviruses), ovine/caprine lentiviruses (e.g., Brazilian caprine lentiviruses, caprine arthritis-encephalitis viruses, Maedi-Visna viruses, Maedi-Visna-like viruses, Maedi-Visna-related viruses, ovine lentiviruses, Visna lentiviruses), Simian AIDS retroviruses (e.g., human T-cell lymphotropic virus type 4), simian immunodeficiency viruses, simian-human immunodeficiency viruses, human lymphotrophic viruses (e.g., type III), simian T-cell lymphotrophic viruses.

In another embodiment, cell lines are engineered to express the HIV proteins necessary for virus particle formation (gagpol proteins), without containing DNA sequences from HIV accessory proteins (tat, vif, vpr, vpu, nef and rev proteins and Rev response element (RRE)). Additionally, no viral sequences (such as cis-acting elements termed constitutive transport elements (CTEs)) will be expressed as RNA of any kind. DNA sequences for a HIV *gagpol* are codon optimized by mutagenesis to improve expression and to reduce the risk of recombination between transfer vector sequences and gagpol messenger RNA. In a particular embodiment, the DNA sequences for HIV *gagpol* are not codon optimized in the overlap region between the *gag* and *pol* sequences and in cis-acting signals necessary for translation of pol.

Alternatively, each of the packaging cell lines described herein can be produced using (1) a nucleotide sequence which comprises a codon optimized gag coding sequence and (2) a nucleotide sequence which comprises a codon optimized pol coding sequence, in place of the nucleotide sequence which comprises a codon optimized gagpol coding sequence. In this embodiment, the gag and pol coding sequences can be completely codon optimized

Benefits of the present invention include the removal of potentially harmful lentivirus accessory proteins and other viral sequences, and the reduction of the risk of recombination to produce replication competent virus.

Packaging cell lines for producing a viral accessory protein independent lentivirus-derived retroviral vector particles comprise a mammalian cell and a retroviral nucleotide sequence comprising a coding sequence for a lentivirus *gagpol* which has been codon optimized. In a particular embodiment the packaging cell lines further comprise a retroviral nucleotide sequence comprising a coding sequence for a heterologous envelope protein. In a second embodiment, the packaging cell lines further comprise a retroviral nucleotide sequence comprising a coding sequence for a heterologous envelope protein and a retroviral nucleotide sequence which comprises a DNA sequence of interest and HIV cis-acting sequences required for packaging, reverse

transcription and integration. In third embodiment, the packaging cell lines further comprise a retroviral nucleotide sequence which comprises a DNA sequence of interest and HIV cis-acting sequences required for packaging, reverse transcription and integration. Alternatively, the packaging cell lines of the present invention comprise a retroviral nucleotide sequence which comprises a codon optimized gag coding sequence and (2) a retroviral nucleotide sequence which comprises a codon optimized pol coding sequence, in place of the retroviral nucleotide sequence which comprises a codon optimized gagpol coding sequence.

The coding sequence(s) for lentivirus *gagpol* which has (have) been codon optimized results in improved expression of the lentivirus gagpol proteins and reduces the risk of recombination between the transfer vector and gagpol messenger RNA. Codon optimization of the coding sequence(s) for lentivirus *gagpol* was obtained by mutagenizing for each particular amino acid residue, specific nucleic acid bases in a codon for the particular amino acid residue to a nucleic acid base which is present in a codon which occurs at a high frequency in genes which are highly expressed for the same amino acid residue. In a particular embodiment, the resulting optimized codon also does not cause introduction of mRNA splicing signals into the codon optimized sequence. Thus, in a particular embodiment, codon optimization of the coding sequence(s) for lentivirus *gagpol* is obtained by mutagenizing for each particular amino acid residue, specific nucleic acid bases in a codon for the particular amino acid residue to a nucleic acid base that is present in a codon which (1) occurs at a high frequency in genes which are highly expressed for the same amino acid residue and (2) does not cause introduction of mRNA splicing signals into the codon optimized sequence. Codon optimization typically results in the removal of nucleic acid base A-rich instability elements.

In a particular embodiment, the coding sequence for a HIV *gagpol* (pNL4-3; available through the AIDS repository, NIH; Adachi *et al.*, *J. Virol.*, 59:284-291 (1986)) has been codon optimized to improve translational efficiency of the HIV gagpol

proteins and reduce the risk of recombination between the transfer vector and HIV gagpol messenger RNA. Two hundred thirty-seven base pairs (237 bp) consisting of the gag pol overlap and cis-acting signals necessary for translation of pol (nucleotides 2583 to 2819 of SEQ ID NO: 12) were not optimized. The HIV *gagpol* sequence obtained using the codon optimization process does not differ at the amino acid level from the wildtype HIV *gagpol* sequence, but differs at the nucleotide level from the HIV *gagpol* sequence. A codon optimized HIV *gag* sequence is shown in Figures 8A-8E (pHDMHgpm2.seq) (SEQ ID NO:4). A codon optimized HIV *pol* sequence is shown in Figures 9A-9L (pHDMHgpm2.seq) (SEQ ID NO:10).

A plasmid comprising DNA sequences which encode codon optimized lentivirus *gagpol* proteins is also referred to herein as a packaging construct. This plasmid includes a promoter which drives the expression of the gagpol proteins, such as the human cytomegalovirus (hCMV) immediate early promoter. This plasmid is defective for the production of the viral envelope and accessory proteins tat, vif, vpr, vpu, nef and rev and the Rev response element (RRE). The packaging construct also does not contain viral sequences which are transcribed into mRNA, such as constitutive transport elements (CTEs).

A packaging construct comprising a codon optimized HIV *gagpol* is depicted in Figure 1 and in Figure 11. Figures 10A-10D depict the DNA sequence (SEQ ID NO:12) for the packaging construct pHDMHgpm2. This packaging construct (pHDMHgpm2) was constructed as follows: Plasmid pMDA.HIVgp mam was generated by chemical synthesis and PCR assembly (which is described in, for example, Stemmer *et al., Gene, 164*:49-53 (1995)) of 215 different oligonucleotides. The DNA sequence for pMDA.HIVgp mam is the same as the DNA sequence for pMDA.HIVgp jtg except for 4.3 kb which was codon optimized using the DNAStar program (LaserGene, Madison, WI). Two hundred thirty-seven base pairs (237 bp) consisting of the gag pol overlap and cis-acting signals necessary for translation of pol (nucleotides 2583 to 2819 of SEQ ID NO: 12) were not optimized due to dual reading

frame constraints. A NsiI site 5' of IN was preserved to aid fusion with wildtype sequences. Several single or double base pair silent mutations were introduced either to prevent potential splice donors and acceptors, or by the synthesis process. pMDA.HIVgp jtg was derived from HIV-1 strain NL4-3. The protease mutation that is present in the NL4-3 NIH GenBank sequence was then repaired (Figure 9B), changing the nucleotide present at position 2948 of SEQ ID NO:12 from a "G" to a "C", thereby producing the codon present at nucleotide positions 2948 to 2950 of SEQ ID NO:12 which encodes an arginine instead of the glycine present in the NL4-3 GenBank amino acid sequence. The resulting plasmid was named pMDHgpmam. The EcoRI-HindIII fragment of pMDHgpmam was inserted into pHDM2b, a high copy version of the pMD vector (Ory, D. *et al., Proc. Natl. Acad. Sci. USA,* 93(21):11400-11406 (1996)), to produce plasmid pHDMHgpm. The sequencing mutation that is present in the RNase domain of the NL4-3 NIH GenBank sequence was repaired (Figure 9H), changing the codon present at nucleotide positions 4724 to 4726 of SEQ ID NO:12 from "GGG" to "AAG", thereby producing a codon encoding a lysine instead of the glycine present in the NL4-3 GenBank amino acid sequence. The resulting plasmid was named pHDMHgpm2. Codon usage frequencies in the codon optimized gagpol open reading frame of the packaging construct pHDMHgpm2 are shown in Figure 2.

As used herein, a heterologous envelope protein permits pseudotyping of particles generated by the packaging construct and includes the G glycoprotein of vesicular stomatitis virus (VSV G) and the amphotropic envelope of the Moloney leukemia virus (MLV). A plasmid comprising a DNA sequence which encodes a heterologous envelope protein is also referred to herein as an envelope coding plasmid.

The terms "mammal" and "mammalian", as used herein, refer to any vertebrate animal, including monotremes, marsupials and placental, that suckle their young and either give birth to living young (eutharian or placental mammals) or are egg-laying (metatharian or nonplacental mammals). Examples of mammalian species include

humans and other primates (e.g., monkeys, chimpanzees), rodents (e.g., rats, mice, guinea pigs) and ruminents (e.g., cows, pigs, horses).

Examples of mammalian cells include human (such as HeLa cells, 293T cells, NIH 3T3 cells), bovine, ovine, porcine, murine (such as embryonic stem cells), rabbit and monkey (such as COS1 cells) cells. The cell may be a non-dividing cell (including hepatocytes, myofibers, hematopoietic stem cells, neurons) or a dividing cell. The cell may be an embryonic cell, bone marrow stem cell or other progenitor cell. Where the cell is a somatic cell, the cell can be, for example, an epithelial cell, fibroblast, smooth muscle cell, blood cell (including a hematopoietic cell, red blood cell, T-cell, B-cell, etc.), tumor cell, cardiac muscle cell, macrophage, dendritic cell, neuronal cell (e.g., a glial cell or astrocyte), or pathogen-infected cell (e.g., those infected by bacteria, viruses, virusoids, parasites, or prions).

Typically, cells isolated from a specific tissue (such as epithelium, fibroblast or hematopoietic cells) are categorized as a "cell-type." The cells can be obtained commercially or from a depository or obtained directly from an animal, such as by biopsy. Alternatively, the cell need not be isolated at all from the animal where, for example, it is desirable to deliver the virus to the animal in gene therapy.

To produce the cell lines of the present invention for producing a viral accessory protein independent lentivirus-derived retroviral vector particles, mammalian host cells are co-transfected with (a) a first plasmid comprising DNA sequence which encode lentivirus *gagpol* proteins, wherein said DNA sequence has been codon optimized by mutagenisis, as described above, to improve expression of the lentivirus gagpol proteins; and (2) a second plasmid comprising a DNA sequence which encodes a heterologous envelope protein, or a retroviral nucleotide sequence which comprises a DNA sequence of interest and lentivirus cis-acting sequences required for packaging, reverse transcription and integration, or both, under conditions appropriate for transfection of the cells.

In a particular embodiment, to produce the cell lines of the present invention for producing viral accessory protein independent HIV-derived retroviral vector particles mammalian host cells were cotransfected with (a) a first plasmid comprising DNA sequence which encode HIV *gagpol* proteins, wherein said DNA sequence has been codon optimized by mutagenisis, as described above, to improve expression of the HIV gagpol proteins; and (2) a second plasmid comprising a DNA sequence which encodes a heterologous envelope protein, or a retroviral nucleotide sequence which comprises a DNA sequence of interest and HIV cis-acting sequences required for packaging, reverse transcription and integration, or both, under conditions appropriate for transfection of the cells.

Virus stocks consisting of viral accessory protein independent lentivirus-derived, particularly HIV-derived, retroviral vector particles of the present invention are produced by maintaining the transfected cells under conditions suitable for virus production (e.g., in an appropriate growth media and for an appropriate period of time). Such conditions, which are not critical to the invention. are generally known in the art. See, e.g., *Sambrook et al., Molecular Cloning: A Laboratory Manual*, Second Edition, Cold Spring Harbor University Press, New York (1989); *Ausubel et al., Current Protocols in Molecular Biology*, John Wiley & Sons, New York (1998); U.S. Patent No. 5,449,614; and U.S. Patent No. 5,460,959, the teachings of which are incorporated herein by reference.

To generate viral accessory protein independent lentivirus-derived retroviral vector particles, mammalian host cells can be co-transfected with (a) a first plasmid comprising DNA sequence which encode lentivirus *gagpol* proteins, wherein said DNA sequence has been codon optimized by mutagenisis, as described above, to improve expression of the lentivirus gagpol proteins; (b) a second plasmid comprising a DNA sequence which encodes a heterologous envelope protein; and (c) a third plasmid comprising a DNA sequence of interest and lentivirus cis-acting sequences required for packaging, reverse transcription and integration. Alternatively, mammalian cells are

transfected with a plasmid comprising a codon optimized DNA sequence encoding a lentivirus gag protein and a plasmid comprising a codon optimized DNA sequence encoding a lentivirus pol protein, in place of the first plasmid comprising a codon optimized DNA sequence encoding both lentivirus gagpol proteins. Alternatively, mammalian host cells are transfected with a plasmid comprising a codon optimized DNA sequence encoding a lentivirus gag protein and a plasmid comprising a codon optimized DNA sequence encoding a lentivirus pol protein, in place of the first plasmid comprising a codon optimized DNA sequence encoding both lentivirus gagpol proteins.

In a particular embodiment, the invention relates to methods of producing viral accessory protein independent HIV-derived retroviral vector particles, comprising co-transfecting mammalian host cells with (a) a first plasmid comprising DNA sequence which encode HIV *gagpol* proteins, wherein said DNA sequence has been codon optimized by mutagenisis, as described above, to improve expression of the HIV gagpol proteins; (b) a second plasmid containing a DNA sequence which encodes a heterologous envelope protein; and (c) a third plasmid comprising a DNA sequence of interest and HIV cis-acting sequences required for packaging, reverse transcription and integration. Alternatively, mammalian host cells are transfected with a plasmid comprising a codon optimized DNA sequence encoding a HIV gag protein and a plasmid comprising a codon optimized DNA sequence encoding a HIV pol protein, in place of the first plasmid comprising a codon optimized DNA sequence encoding both HIV gagpol proteins.

Virus particles produced by the methods described herein, using a codon optimized HIV packaging construct produced as described herein, were compared by Western analysis with virus particles produced as described in Naldini *et al., Science,* *272*:263-267 (1996), using the packaging construct plasmid pCMVΔR8.2. Both the immunological reactivity and the proteolytic processing were confirmed to be indistinguishable.

A plasmid comprising a DNA sequence of interest and HIV cis-acting sequences required for packaging, reverse transcription and integration is also referred to herein as a transfer vector. A transfer vector, as used herein, refers to a vehicle which is used to introduce a DNA of interest into a eurkaryotic cell, particularly a mammalian cell. Figure 3 depicts an example of a transfer vector.

DNA sequence of interest, as used herein, include all or a portion of a gene or genes encoding a nucleic acid product whose expression in a cell or a mammal is desired. In a particular embodiment, the nucleic acid product is a heterologous therapeutic protein. Examples of therapeutic proteins include antigens or immunogens, such as a polyvalent vaccine, cytokines, tumor necrosis factor, interferons, interleukins, adenosine deaminase, insulin, T-cell receptors, soluble CD4, growth factors, such as epidermal growth factor, human growth factor, insulin-like growth factors, fibroblast growth factors), blood factors, such as Factor VIII, Factor IX, cytochrome b, glucocerebrosidase, ApoE, ApoC, ApoAI, the LDL receptor, negative selection markers or "suicide proteins", such as thymidine kinase (including the HSV, CMV, VZV TK), anti-angiogenic factors, Fc receptors, plasminogen activators, such as t-PA, u-PA and streptokinase, dopamine, MHC, tumor suppressor genes such as p53 and Rb, monoclonal antibodies or antigen binding fragments thereof, drug resistance genes, ion channels, such as a calcium channel or a potassium channel, adrenergic receptors, hormones (including growth hormones) and anti-cancer agents. In another embodiment, the nucleic acid product is a gene product to be expressed in a cell or a mammal and which product is otherwise defective or absent in the cell or mammal. For example, the nucleic acid product can be a functional gene(s) which is defective or absent in the cell or mammal.

DNA sequence of interest includes DNA sequences (control sequences) which are necessary to drive the expression of the gene or genes. The control sequences are operably linked to the gene. The term "operably linked", as used herein, is defined to mean that the gene is linked to control sequences in a manner which allows expression

of the gene (or the nucleic acid sequence). Generally, operably linked means contiguous.

Control sequences include a transcriptional promoter, an optional operator sequence to control transcription, a sequence encoding suitable mRNA ribosomal binding sites and sequences which control termination of transcription and translation. In a particular embodiment, a recombinant gene encoding a desired nucleic acid product can be placed under the regulatory control of a promoter which can be induced or repressed, thereby offering a greater degree of control with respect to the level of the product produced.

As used herein, the term "promoter" refers to a sequence of DNA, usually upstream (5') of the coding region of a structural gene, which controls the expression of the coding region by providing recognition and binding sites for RNA polymerase and other factors which may be required for initiation of transcription. Suitable promoters are well known in the art. Exemplary promoters include the SV40, CMV and human elongation factor (EFI) promoters. Other suitable promoters are readily available in the art (see, e.g., Ausubel *et al., Current Protocols in Molecular Biology,* John Wiley & Sons, Inc., New York (1998); Sambrook *et al., Molecular Cloning: A Laboratory Manual,* 2nd edition, Cold Spring Harbor University Press, New York (1989); and U.S. Patent No. 5,681,735).

A DNA sequence of interest can be isolated from nature, modified from native sequences or manufactured *de novo*, as described in, for example, Ausubel *et al., Current Protocols in Molecular Biology*, John Wiley & Sons, New York (1998); and Sambrook *et al., Molecular Cloning: A Laboratory Manual*, 2nd edition, Cold Spring Harbor University Press, New York. (1989). DNA sequences can be isolated and fused together by methods known in the art, such as exploiting and manufacturing compatible cloning or restriction sites.

The packaging cell lines and viral particles of the present invention can be used, in vitro, in vivo and ex vivo, to introduce DNA of interest into a eukaryotic cell (e.g., a

mammalian cell) or a mammal (e.g., a human or other mammal or vertebrate). The cells can be obtained commercially or from a depository or obtained directly from a mammal, such as by biopsy. The cells can be obtained from a mammal to whom they will be returned or from another/different mammal of the same or different species. For example, using the packaging cell lines or viral particles of the present invention, DNA of interest can be introduced into nonhuman cells, such as pig cells, which are then introduced into a human. Alternatively, the cell need not be isolated from the mammal where, for example, it is desirable to deliver vial particles of the present invention to the mammal in gene therapy.

Ex vivo therapy has been described, for example, in Kasid *et al., Proc. Natl. Acad. Sci. USA, 87*:473 (1990); Rosenberg *et al., N. Engl. J. Med., 323*:570 (1990); Williams *et al., Nature, 310*:476 (1984); Dick *et al., Cell, 42*:71 (1985); Keller *et al., Nature, 318*:149 (1985); and Anderson *et al.*, United States Patent No. 5,399,346.

Methods for administering (introducing) viral particles directly to a mammal are generally known to those practiced in the art. For example, modes of administration include parenteral, injection, mucosal, systemic, implant, intraperitoneal, oral, intradermal, transdermal (e.g., in slow release polymers), intramuscular, intravenous including infusion and/or bolus injection, subcutaneous, topical, epidural, etc. Viral particles of the present invention can, preferably, be administered in a pharmaceutically acceptable carrier, such as saline, sterile water, Ringer's solution, and isotonic sodium chloride solution.

The dosage of a viral particle of the present invention administered to a mammal, including frequency of administration, will vary depending upon a variety of factors, including mode and route of administration; size, age, sex, health, body weight and diet of the recipient mammal; nature and extent of symptoms of the disease or disorder being treated; kind of concurrent treatment, frequency of treatment, and the effect desired.

The teachings of all the articles, patents, patent applications and GenBank sequences cited herein are incorporated by reference in their entirety.

While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

Claims

CLAIMS

What is claimed is:

1. A packaging cell line for producing a viral accessory protein independent HIV-derived retroviral vector particle comprising:
   a) a mammalian cell;
   b) a first retroviral nucleotide sequence in the cell which comprises a coding sequence for a HIV *gagpol*, wherein said coding sequence has been mutagenized to improve expression of the HIV gagpol proteins:
   c) a second retroviral nucleotide sequence in the cell which comprises the coding sequence for a heterologous envelope protein; and
   d) a third retroviral nucleotide sequence in the cell which comprises a DNA sequence of interest and HIV cis-acting sequences required for packaging, reverse transcription and integration.

2. A packaging cell line of Claim 1 wherein the heterologous envelope protein is the G glycoprotein of vesicular stomatitis virus (VSV G).

3. A packaging cell line of Claim 1 wherein the heterologous envelope protein is the amphotropic envelope of the Moloney leukemia virus.

4. A packaging cell line of Claim 1 wherein the DNA sequence of interest encodes a heterologous therapeutic protein.

5. A packaging cell line comprising:
   a) a mammalian cell;

b) a first retroviral nucleotide sequence in the cell which comprises a coding sequence for a HIV *gagpol*, wherein said coding sequence has been mutagenized to improve expression of the HIV gagpol proteins; and

c) a second retroviral nucleotide sequence in the cell which comprises a DNA sequence of interest and HIV cis-acting sequences required for packaging, reverse transcription and integration.

6. A packaging cell line of Claim 5 wherein the DNA sequence of interest encodes a heterologous therapeutic protein.

7. A packaging cell line comprising:

a) a mammalian cell;

b) a first retroviral nucleotide sequence in the cell which comprises a coding sequence for a HIV *gagpol*, wherein said coding sequence has been mutagenized to improve expression of the HIV gagpol proteins; and

c) a second retroviral nucleotide sequence in the cell which comprises the coding sequence for a heterologous envelope protein.

8. A method of producing a packaging cell line for producing a viral accessory protein independent HIV-derived retroviral vector particle, comprising co-transfecting mammalian host cells with:

a) a first plasmid comprising a DNA sequence which encodes HIV *gagpol* proteins, wherein said DNA sequence has been mutagenized to improve expression of the HIV gag and pol proteins;

b) a second plasmid comprising a DNA sequence which encodes a heterologous envelope protein; and

c) a third plasmid comprising a DNA sequence of interest and HIV cis-acting sequences required for packaging, reverse transcription and integration.

9. A method of Claim 8 wherein the heterologous envelope protein is the G glycoprotein of vesicular stomatitis virus (VSV G).

10. A method of Claim 8 wherein the heterologous envelope protein is the amphotropic envelope of the Moloney leukemia virus.

11. A method of Claim 8 wherein the DNA sequence of interest is a heterologous therapeutic protein.

12. A method of producing a viral accessory protein independent HIV-derived retroviral vector particle comprising co-transfecting mammalian host cells with:

a) a first plasmid comprising a DNA sequence which encodes HIV *gagpol* proteins, wherein said DNA sequence has been mutagenized to improve expression of the HIV gagpol proteins;

b) a second plasmid comprising a DNA sequence which encodes a heterologous envelope protein; and

c) a third plasmid comprising a DNA sequence of interest and HIV cis-acting sequences required for packaging, reverse transcription and integration.

13. A method of Claim 12 wherein the heterologous envelope protein is the G glycoprotein of vesicular stomatitis virus (VSV G).

14. A method of Claim 12 wherein the heterologous envelope protein is the amphotropic envelope of the Moloney leukemia virus.

15. A method of Claim 12 wherein the DNA sequence of interest encodes a heterologous therapeutic protein.

16. A packaging cell line for producing a viral accessory protein independent lentivirus-derived retroviral vector particle comprising:

a) a mammalian cell;

b) a first retroviral nucleotide sequence in the cell which comprises a coding sequence for a lentivirus *gagpol*, wherein said coding sequence has been mutagenized to improve expression of the lentivirus gagpol proteins;

c) a second retroviral nucleotide sequence in the cell which comprises the coding sequence for a heterologous envelope protein; and

d) a third retroviral nucleotide sequence in the cell which comprises a DNA sequence of interest and lentivirus cis-acting sequences required for packaging, reverse transcription and integration.

17. A packaging cell line of Claim 16 wherein the heterologous envelope protein is the G glycoprotein of vesicular stomatitis virus (VSV G).

18. A packaging cell line of Claim 16 wherein the heterologous envelope protein is the amphotropic envelope of the Moloney leukemia virus.

19. A packaging cell line of Claim 16 wherein the DNA sequence of interest encodes a heterologous therapeutic protein.

20. A packaging cell line comprising:

a) a mammalian cell;

b) a first retroviral nucleotide sequence in the cell which comprises a coding sequence for lentivirus *gagpol*, wherein said coding sequence has been mutagenized to improve expression of the lentivirus gagpol proteins; and

c) a second retroviral nucleotide sequence in the cell which comprises a DNA sequence of interest and lentivirus cis-acting sequences required for packaging, reverse transcription and integration.

21. A packaging cell line of Claim 20 wherein the DNA sequence of interest encodes a heterologous therapeutic protein.

22. A packaging cell line comprising:

a) a mammalian cell;

b) a first retroviral nucleotide sequence in the cell which comprises a coding sequence for lentivirus *gagpol*, wherein said coding sequence has been mutagenized to improve expression of the lentivirus gagpol proteins; and

c) a second retroviral nucleotide sequence in the cell which comprises the coding sequence for a heterologous envelope protein.

23. A method of producing a packaging cell line for producing a viral accessory protein independent lentivirus-derived retroviral vector particle, comprising co-transfecting mammalian host cells with:

a) a first plasmid comprising a DNA sequence which encodes lentivirus *gagpol* proteins, wherein said DNA sequence has been mutagenized to improve expression of the lentivirus gag and pol proteins;

b) a second plasmid comprising a DNA sequence which encodes a heterologous envelope protein; and

c) a third plasmid comprising a DNA sequence of interest and lentivirus cis-acting sequences required for packaging, reverse transcription and integration.

24. A method of Claim 23 wherein the heterologous envelope protein is the G glycoprotein of vesicular stomatitis virus (VSV G).

25. A method of Claim 23 wherein the heterologous envelope protein is the amphotropic envelope of the Moloney leukemia virus.

26. A method of Claim 23 wherein the DNA sequence of interest is a heterologous therapeutic protein.

27. A method of producing a viral accessory protein independent lentivirus-derived retroviral vector particle comprising co-transfecting mammalian host cells with:

a) a first plasmid comprising a DNA sequence which encodes lentivirus *gagpol* proteins, wherein said DNA sequence has been mutagenized to improve expression of the lentivirus gagpol proteins;

b) a second plasmid comprising a DNA sequence which encodes a heterologous envelope protein; and

c) a third plasmid comprising a DNA sequence of interest and lentivirus cis-acting sequences required for packaging, reverse transcription and integration.

28. A method of Claim 27 wherein the heterologous envelope protein is the G glycoprotein of vesicular stomatitis virus (VSV G).

29. A method of Claim 27 wherein the heterologous envelope protein is the amphotropic envelope of the Moloney leukemia virus.

30. A method of Claim 27 wherein the DNA sequence of interest encodes a heterologous therapeutic protein.

31. A viral accessory protein independent HIV-derived retroviral vector particle produced by the method comprising co-transfecting mammalian host cells with:

a) a first plasmid comprising a DNA sequence which encodes HIV *gagpol* proteins, wherein said DNA sequence has been mutagenized to improve expression of the HIV gagpol proteins;

b) a second plasmid comprising a DNA sequence which encodes a heterologous envelope protein; and

c) a third plasmid comprising a DNA sequence of interest and HIV cis-acting sequences required for packaging, reverse transcription and integration.

32. A method of Claim 31 wherein the heterologous envelope protein is the G glycoprotein of vesicular stomatitis virus (VSV G).

33. A method of Claim 31 wherein the heterologous envelope protein is the amphotropic envelope of the Moloney leukemia virus.

34. A method of Claim 31 wherein the DNA sequence of interest encodes a heterologous therapeutic protein.

35. A viral accessory protein independent lentivirus-derived retroviral vector particle produced by the method comprising co-transfecting mammalian host cells with:

a) a first plasmid comprising a DNA sequence which encodes lentivirus—*gagpol* proteins, wherein said DNA sequence has been mutagenized to improve expression of the lentivirus gagpol proteins;

b) a second plasmid comprising a DNA sequence which encodes a heterologous envelope protein; and

c) a third plasmid comprising a DNA sequence of interest and lentivirus cis-acting sequences required for packaging, reverse transcription and integration.

36. A method of Claim 35 wherein the heterologous envelope protein is the G glycoprotein of vesicular stomatitis virus (VSV G).

37. A method of Claim 35 wherein the heterologous envelope protein is the amphotropic envelope of the Moloney leukemia virus.

38. A method of Claim 35 wherein the DNA sequence of interest encodes a heterologous therapeutic protein.

39. Isolated DNA encoding a codon optimized HIV *gagpol*.

40. Isolated DNA encoding a codon optimized HIV *gag*.

41. Isolated DNA of Claim 40 comprising the nucleotide sequence of SEQ ID NO:4.

42. Isolated DNA encoding a codon optimized HIV *pol*.

43. Isolated DNA of Claim 42 comprising the nucleotide sequence of SEQ ID NO:10.

44. A method of introducing a DNA sequence of interest into a mammal comprising introducing into said mammal a viral accessory protein independent HIV-derived retroviral vector particle comprising the DNA sequence of interest.

45. The method of Claim 44 wherein the mammal is a human.

46. The method of Claim 44 wherein the DNA sequence of interest encodes a heterologous therapeutic protein.

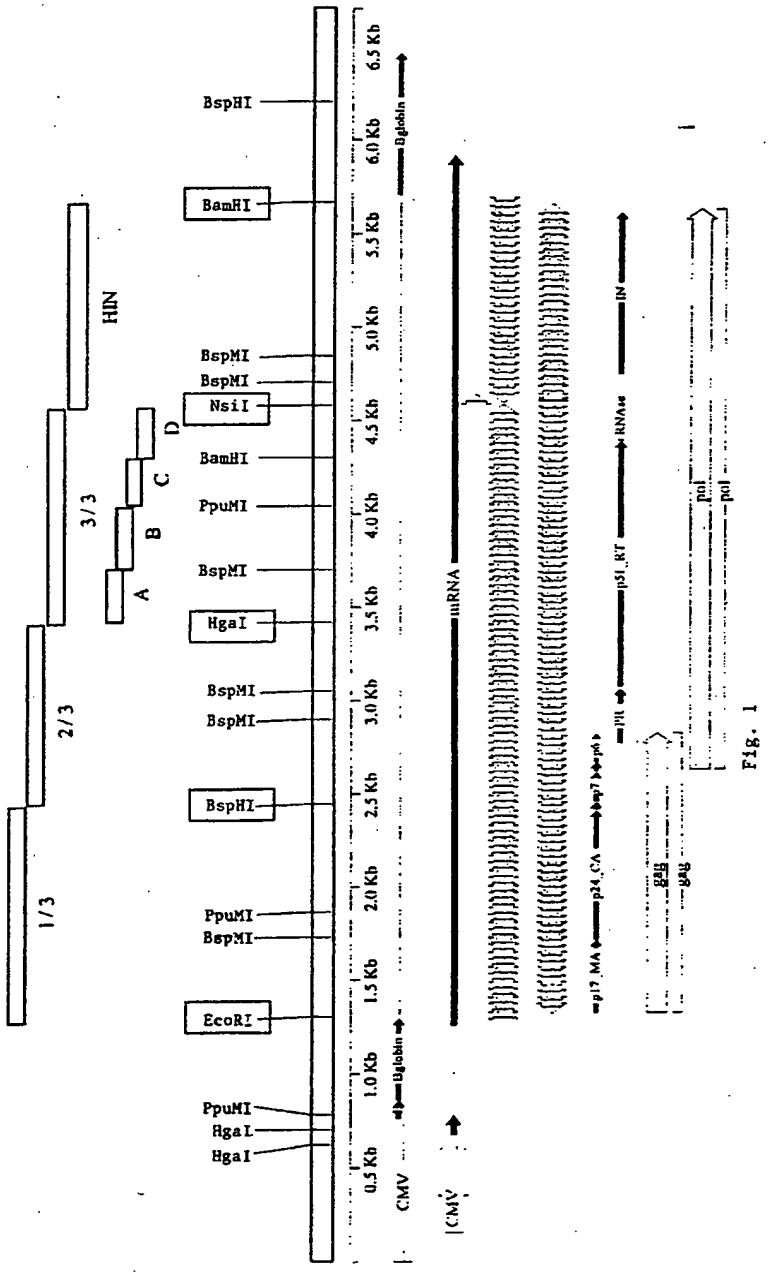
47. A method of introducing a DNA sequence of interest into a mammal comprising the steps of:

a) introducing into cells a viral accessory protein independent HIV-derived retroviral vector particle comprising the DNA sequence of interest; and

b) returning the cells obtained in step a) to the mammal.

48. The method of Claim 47 wherein the mammal is a human.

49. The method of Claim 47 wherein the DNA sequence of interest is a heterologous therapeutic protein.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BamHI
BspMI
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PpuMI
BspMI
EcoRI
PpuMI
HgaI
HgaI
HIN
1/3
2/3
3/3
A
B
C
D
0.5 Kb
1.0 Kb
1.5 Kb
2.0 Kb
2.5 Kb
3.0 Kb
3.5 Kb
4.0 Kb
4.5 Kb
5.0 Kb
5.5 Kb
6.0 Kb
6.5 Kb
CMV
Ugobin
Bglobin
CMV
tuRNA
p17 MA
p24 CA
p7
p6
PR
p51 RT
RNAse
IN
gag
pol

Fig. 1

Codon Usage Frequencies

Amino Acid	pNL4-3 gagpol	mam	Amino Acid	pNL4-3 gagpol	mam	Amino Acid	pNL4-3 gagpol	mam
gca Ala(A)	58	13	gga Gly(G)	55	14	cca Pro(P)	53	16
gcc Ala(A)	23	53	ggc Gly(G)	12	50	ccc Pro(P)	17	48
gcg Ala(A)	5	17	ggg Gly(G)	27	24	ccg Pro(P)	2	17
gcu Ala(A)	14	17	ggu Gly(G)	6	12	ccu Pro(P)	27	19
aga Arg(R)	63	10	cac His(H)	24	79	agc Ser (S)	29	34
agg Arg(R)	30	18	cau His(H)	76	21	agu Ser (S)	26	10
cga Arg(R)	4	6				uca Ser (S)	26	5
cgc Arg(R)	0	37	aua Ile(I)	57	5	ucc Ser (S)	7	28
cgg Arg(R)	3	21	auc Ile(I)	17	77	ucg Ser (S)	4	9
cgu Arg(R)	0	7	auu Ile(I)	26	18	ucu Ser (S)	6	13
aac Asn(N)	27	78	cua Leu(L)	15	3	aca Thr (T)	52	14
aau Asn(N)	73	22	cuc Leu(L)	10	26	acc Thr (T)	18	57
gac Asp(D)	40	75	cug Leu(L)	11	58	acg Thr (T)	1	15
gau Asp(D)	60	25	cuu Leu(L)	11	5	acu Thr (T)	29	14
ugc Cys (C)	14	68	uua Leu(L)	40	2	ugg Trp(W)	100	100
ugu Cys (C)	26	32	uug Leu(L)	13	6			
			aaa Lys (K)	69	18	uac Tyr (Y)	26	74
caa Gln(Q)	56	12	aag Lys (K)	31	82	uau Tyr (Y)	74	26
cag Gln(Q)	44	88						
			aug Met (M)	100	100	gua Val (V)	58	5
						guc Val (V)	13	25
gaa Glu(E)	70	25	uuc Phe (F)	40	80	gug Val (V)	16	64
gag Glu(E)	30	75	uuu Phe (F)	60	20	guu Val (V)	14	7

Fig. 2

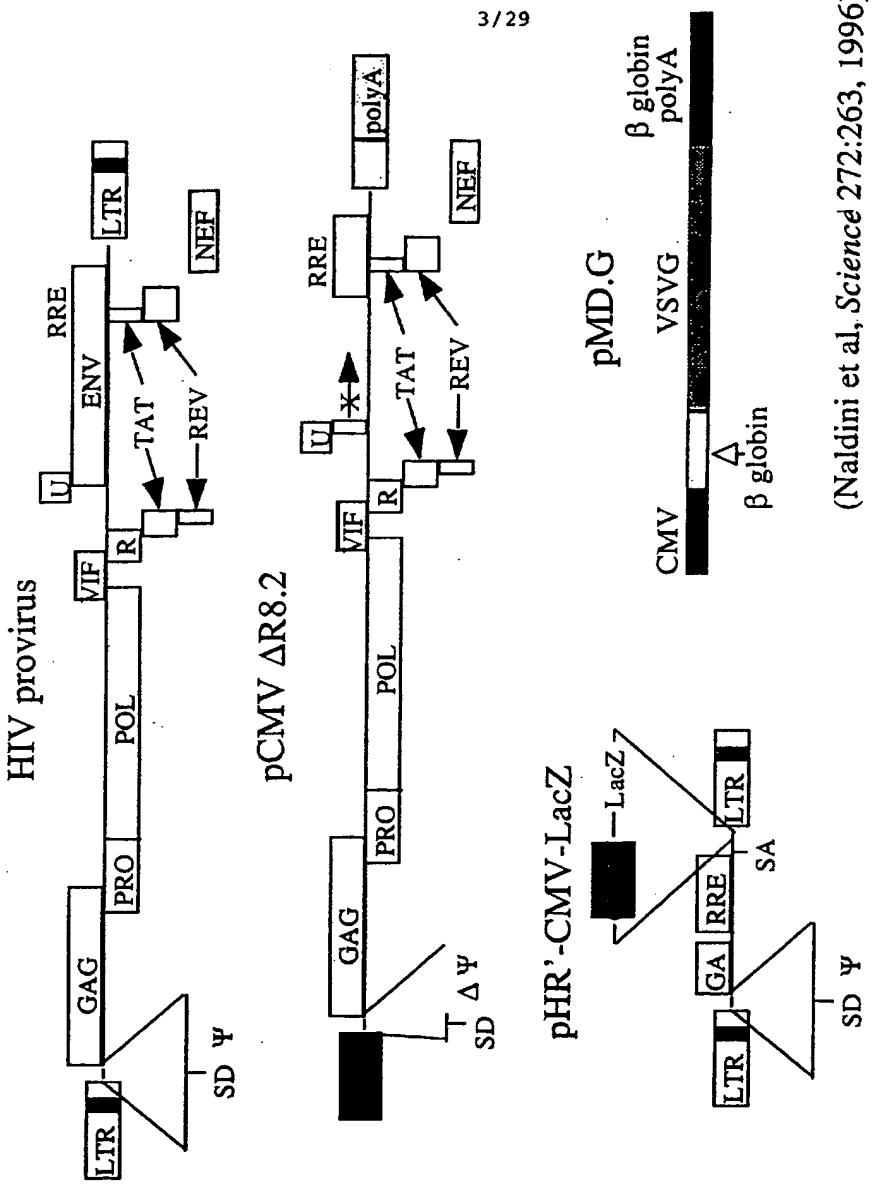
HIV provirus
LTR
GAG
PRO
POL
ENV
VIF
RRE
TAT
REV
NEF
U
R
SD
Ψ
pCMV ΔR8.2
polyA
Δ Ψ
pMD.G
VSVG
β globin
polyA
CMV
pHR'-CMV-LacZ
LacZ
SA
GA
(Naldini et al, Science 272:263, 1996)

Fig. 3

Rev

- Regulates HIV gene expression by promoting cytoplasmic levels of unspliced and singly spliced mRNAs
- Postulated to affect splicing, stability, transport, and translation

Fig. 4

Codon Optimization of HIV *gagpol*

- Remove A-rich instability elements
- Improve translational efficiency
- Reduce risk of recombination with transfer vector

Fig. 5

Inactivation of Inhibitory Sequences in *gag*

Schwartz, S., *et al.*

336

atg ggt gcg aga gcg tca gta tta agc ggg gga gaa tta gat cga tgg gaa aaa att cgg

396 **M1**

tta agg cca ggg gga aag aaa aaa tat aaa tta aaa cat ata gta tgg gca agc agg gag

456 G G C GC G C C

cta gaa cga ttc gca gtt aat cct ggc ctg tta gaa aca tca gaa ggc tgt aga caa ata

516 **M2**

ctg gga cag cta caa cca tcc ctt cag aca gga tca gaa gaa ctt aga tca tta tat aat

576 **M3** G G C C C C

aca gta gca acc ctc tat tgt gtg cat caa agg ata gag ata aaa gac acc aag gaa gct

C GC C C G

636 **M4**

tta gac aag ata gag gaa gag caa aac aaa agt aag aaa aaa gca cag caa gca gca gct

696 GTCC G G C G

gac aca gga cac agc aat cag gtc agc caa aat tac

Fig. 6

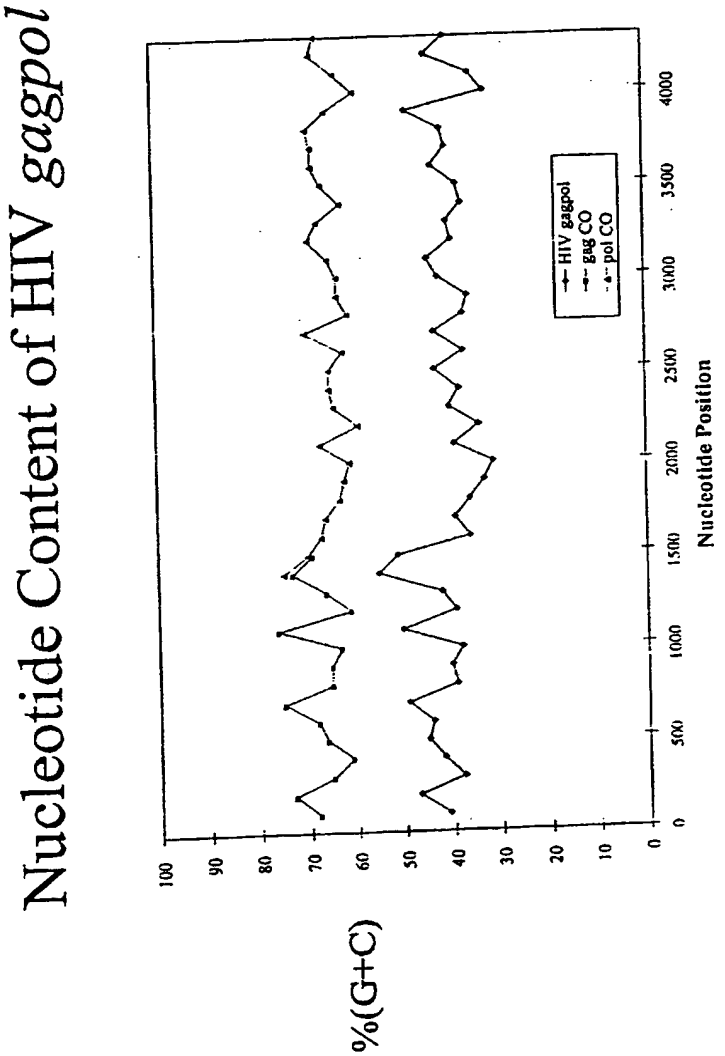
Nucleotide Content of HIV gagpol
%(G+C)
100
90
80
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
3000
3500
4000
Nucleotide Position
HIV gagpol
gag CO
pol CO

Fig. 7

Alignment Report of Codon optimization (gag).MEG, using Clustal method with PAM250 residue weight table.

```
                                  810
792   M  G  A  R  A  S  V  L  S  G  G  E  L  D  K   NL4-3 genbank.SEQ
792   ATG GGT GCG AGA GCG TCG GTA TTA AGC GGG GGA GAA TTA GAT AAA
1319  M  G  A  R  A  S  V  L  S  G  G  E  L  D  K   pHDMHgpm2.seq
1319  ATG GGC GCC CGC GCC TCC GTG CTG TCC GGC GGC GAG CTG GAC AAG

      840                                 870
837   W  E  K  I  R  L  R  P  G  G  K  K  Q  Y  K   NL4-3 genbank.SEQ
837   TGG GAA AAA ATT CGG TTA AGG CCA GGG GGA AAG AAA CAA TAT AAA
1364  W  E  K  I  R  L  R  P  G  G  K  K  Q  Y  K   pHDMHgpm2.seq
1364  TGG GAG AAG ATC CGC CTG CGC CCC GGC GGC AAG AAG CAG TAC AAG

                        900
882   L  K  H  I  V  W  A  S  R  E  L  E  R  F  A   NL4-3 genbank.SEQ
882   CTA AAA CAT ATA GTA TGG GCA AGC AGG GAG CTA GAA CGA TTC GCA
1409  L  K  H  I  V  W  A  S  R  E  L  E  R  F  A   pHDMHgpm2.seq
1409  CTG AAG CAC ATC GTG TGG GCC TCC CGC GAG CTG GAG CGC TTC GCC

      930                                 960
927   V  N  P  G  L  L  E  T  S  E  G  C  R  Q  I   NL4-3 genbank.SEQ
927   GTT AAT CCT GGC CTT TTA GAG ACA TCA GAA GGC TGT AGA CAA ATA
1454  V  N  P  G  L  L  E  T  S  E  G  C  R  Q  I   pHDMHgpm2.seq
1454  GTG AAC CCC GGC CTG CTG GAG ACC TCC GAG GGC TGC CGC CAG ATC

                        990
972   L  G  Q  L  Q  P  S  L  Q  T  G  S  E  E  L   NL4-3 genbank.SEQ
972   CTG GGA CAG CTA CAA CCA TCC CTT CAG ACA GGA TCA GAA GAA CTT
1499  L  G  Q  L  Q  P  S  L  Q  T  G  S  E  E  L   pHDMHgpm2.seq
1499  CTG GGC CAG CTG CAG CCC TCC CTG CAA ACC GGC TCC GAG GAG CTG

      1020                                1050
1017  R  S  L  Y  N  T  I  A  V  L  Y  C  V  H  Q   NL4-3 genbank.SEQ
1017  AGA TCA TTA TAT AAT ACA ATA GCA GTC CTC TAT TGT GTG CAT CAA
1544  R  S  L  Y  N  T  I  A  V  L  Y  C  V  H  Q   pHDMHgpm2.seq
1544  CGC TCC CTG TAC AAC ACC ATC GCC GTG CTG TAC TGC GTG CAC CAG

                        1080
1062  R  I  D  V  K  D  T  K  E  A  L  D  K  I  E   NL4-3 genbank.SEQ
1062  AGG ATA GAT GTA AAA GAC ACC AAG GAA GCC TTA GAT AAG ATA GAG
1589  R  I  D  V  K  D  T  K  E  A  L  D  K  I  E   pHDMHgpm2.seq
1589  CGC ATC GAC GTG AAG GAC ACC AAG GAG GCC CTG GAC AAG ATC GAG

      1110                                1140
1107  E  E  Q  N  K  S  K  K  K  A  Q  Q  A  A  A   NL4-3 genbank.SEQ
1107  GAA GAG CAA AAC AAA AGT AAG AAA AAG GCA CAG CAA GCA GCA GCT
1634  E  E  Q  N  K  S  K  K  K  A  Q  Q  A  A  A   pHDMHgpm2.seq
1634  GAG GAG CAG AAC AAG TCC AAG AAG AAG GCC CAG CAG GCC GCC GCC
```

Fig. 8A

Alignment Report of Codon optimization (gag).MEG, using Clustal method with PAM250 residue weight table.

```
                                  1170
1152  D  T  G  N  N  S  Q  V  S  Q  N  Y  P  I  V  NL4-3 genbank.SEQ
1152  GAC ACA GGA AAC AAC AGC CAG GTC AGC CAA AAT TAC CCT ATA GTG
1679  D  T  G  N  N  S  Q  V  S  Q  N  Y  P  I  V  pHDMHgpm2.seq
1679  GAC ACC GGC AAC AAC TCC CAG GTG TCC CAG AAC TAC CCC ATC GTG

      1200                                  1230
1197  Q  N  L  Q  G  Q  M  V  H  Q  A  I  S  P  R  NL4-3 genbank.SEQ
1197  CAG AAC CTC CAG GGG CAA ATG GTA CAT CAG GCC ATA TCA CCT AGA
1724  Q  N  L  Q  G  Q  M  V  H  Q  A  I  S  P  R  pHDMHgpm2.seq
1724  CAG AAC CTG CAG GGC CAG ATG GTG CAC CAG GCC ATC TCC CCC CGC

                                  1260
1242  T  L  N  A  W  V  K  V  V  E  E  K  A  F  S  NL4-3 genbank.SEQ
1242  ACT TTA AAT GCA TGG GTA AAA GTA GTA GAA GAG AAG GCT TTC AGC
1769  T  L  N  A  W  V  K  V  V  E  E  K  A  F  S  pHDMHgpm2.seq
1769  ACC CTG AAC GCC TGG GTG AAG GTG GTG GAG GAG AAG GCC TTC TCC

      1290                                  1320
1287  P  E  V  I  P  M  F  S  A  L  S  E  G  A  T  NL4-3 genbank.SEQ
1287  CCA GAA GTA ATA CCC ATG TTT TCA GCA TTA TCA GAA GGA GCC ACC
1814  P  E  V  I  P  M  F  S  A  L  S  E  G  A  T  pHDMHgpm2.seq
1814  CCC GAA GTC ATC CCC ATG TTC TCC GCC CTG TCC GAG GGC GCC ACC

                                  1350
1332  P  Q  D  L  N  T  M  L  N  T  V  G  G  H  Q  NL4-3 genbank.SEQ
1332  CCA CAA GAT TTA AAT ACC ATG CTA AAC ACA GTG GGG GGA CAT CAA
1859  P  Q  D  L  N  T  M  L  N  T  V  G  G  H  Q  pHDMHgpm2.seq
1859  CCC CAG GAC CTG AAC ACC ATG CTG AAC ACC GTG GGC GGC CAC CAG

      1380                                  1410
1377  A  A  M  Q  M  L  K  E  T  I  N  E  E  A  A  NL4-3 genbank.SEQ
1377  GCA GCC ATG CAA ATG TTA AAA GAG ACC ATC AAT GAG GAA GCT GCA
1904  A  A  M  Q  M  L  K  E  T  I  N  E  E  A  A  pHDMHgpm2.seq
1904  GCC GCC ATG CAG ATG CTG AAG GAG ACC ATC AAC GAG GAG GCC GCC

                                  1440
1422  E  W  D  R  L  H  P  V  H  A  G  P  I  A  P  NL4-3 genbank.SEQ
1422  GAA TGG GAT AGA TTG CAT CCA GTG CAT GCA GGG CCT ATT GCA CCA
1949  E  W  D  R  L  H  P  V  H  A  G  P  I  A  P  pHDMHgpm2.seq
1949  GAG TGG GAC CGC CTG CAC CCC GTG CAC GCC GGC CCC ATC GCC CCC

      1470                                  1500
1467  G  Q  M  R  E  P  R  G  S  D  I  A  G  T  T  NL4-3 genbank.SEQ
1467  GGC CAG ATG AGA GAA CCA AGG GGA AGT GAC ATA GCA GGA ACT ACT
1994  G  Q  M  R  E  P  R  G  S  D  I  A  G  T  T  pHDMHgpm2.seq
1994  GGC CAG ATG CGC GAG CCC CGC GGC TCC GAC ATC GCC GGC ACC ACC
```

Fig. 8B

Alignment Report of Codon optimization (gag).MEG, using Clustal method with PAM250 residue weight table.

```
                                    1530
1512  S  T  L  Q  E  Q  I  G  W  M  T  H  N  P  P  NL4-3 genbank.SEQ
1512  AGT ACC CTT CAG GAA CAA ATA GGA TGG ATG ACA CAT AAT CCA CCT
2039  S  T  L  Q  E  Q  I  G  W  M  T  H  N  P  P  pHDMHgpm2.seq
2039  TCC ACC CTG CAA GAG CAG ATC GGC TGG ATG ACC CAC AAC CCC CCC

      1560                                1590
1557  I  P  V  G  E  I  Y  K  R  W  I  I  L  G  L  NL4-3 genbank.SEQ
1557  ATC CCA GTA GGA GAA ATC TAT AAA AGA TGG ATA ATC CTG GGA TTA
2084  I  P  V  G  E  I  Y  K  R  W  I  I  L  G  L  pHDMHgpm2.seq
2084  ATC CCC GTG GGC GAG ATC TAC AAG CGC TGG ATC ATC CTG GGC CTG

                                    1620
1602  N  K  I  V  R  M  Y  S  P  T  S  I  L  D  I  NL4-3 genbank.SEQ
1602  AAT AAA ATA GTA AGA ATG TAT AGC CCT ACC AGC ATT CTG GAC ATA
2129  N  K  I  V  R  M  Y  S  P  T  S  I  L  D  I  pHDMHgpm2.seq
2129  AAC AAG ATC GTG CGC ATG TAC TCC CCC ACC TCC ATC CTG GAC ATC

      1650                                1680
1647  R  Q  G  P  K  E  P  F  R  D  Y  V  D  R  F  NL4-3 genbank.SEQ
1647  AGA CAA GGA CCA AAG GAA CCC TTT AGA GAC TAT GTA GAC CGA TTC
2174  R  Q  G  P  K  E  P  F  R  D  Y  V  D  R  F  pHDMHgpm2.seq
2174  CGC CAG GGC CCC AAG GAG CCC TTC CGC GAC TAC GTG GAC CGC TTC

                                    1710
1692  Y  K  T  L  R  A  E  Q  A  S  Q  E  V  K  N  NL4-3 genbank.SEQ
1692  TAT AAA ACT CTA AGA GCC GAG CAA GCT TCA CAA GAG GTA AAA AAT
2219  Y  K  T  L  R  A  E  Q  A  S  Q  E  V  K  N  pHDMHgpm2.seq
2219  TAC AAG ACC CTG CGC GCC GAG CAG GCC TCC CAG GAG GTA AAG AAC

      1740                                1770
1737  W  M  T  E  T  L  L  V  Q  N  A  N  P  D  C  NL4-3 genbank.SEQ
1737  TGG ATG ACA GAA ACC TTG TTG GTC CAA AAT GCG AAC CCA GAT TGT
2264  W  M  T  E  T  L  L  V  Q  N  A  N  P  D  C  pHDMHgpm2.seq
2264  TGG ATG ACC GAG ACC CTG CTG GTG CAG AAC GCC AAC CCC GAC TGC

                                    1800
1782  K  T  I  L  K  A  L  G  P  G  A  T  L  E  E  NL4-3 genbank.SEQ
1782  AAG ACT ATT TTA AAA GCA TTG GGA CCA GGA GCG ACA CTA GAA GAA
2309  K  T  I  L  K  A  L  G  P  G  A  T  L  E  E  pHDMHgpm2.seq
2309  AAG ACC ATC CTG AAG GCC CTG GGC CCC GGC GCC ACC CTG GAG GAG

      1830                                1860
1827  M  M  T  A  C  Q  G  V  G  G  P  G  H  K  A  NL4-3 genbank.SEQ
1827  ATG ATG ACA GCA TGT CAG GGA GTG GGG GGA CCC GGC CAT AAA GCA
2354  M  M  T  A  C  Q  G  V  G  G  P  G  H  K  A  pHDMHgpm2.seq
2354  ATG ATG ACC GCC TGC CAG GGC GTG GGC GGC CCC GGC CAC AAG GCC
```

Fig. 8C

Alignment Report of Codon optimization (gag).MEG, using Clustal method with PAM250 residue weight table.

```
                                1890
1872  R  V  L  A  E  A  M  S  Q  V  T  N  P  A  T   NL4-3 genbank.SEQ
1872  AGA GTT TTG GCT GAA GCA ATG AGC CAA GTA ACA AAT CCA GCT ACC
2399  R  V  L  A  E  A  M  S  Q  V  T  N  P  A  T   pHDMHgpm2.seq
2399  CGC GTG CTG GCC GAG GCC ATG TCC CAA GTC ACC AAC CCC GCC ACC

      1920                                    1950
1917  I  M  I  Q  K  G  N  F  R  N  Q  R  K  T  V   NL4-3 genbank.SEQ
1917  ATA ATG ATA CAG AAA GGC AAT TTT AGG AAC CAA AGA AAG ACT GTT
2444  I  M  I  Q  K  G  N  F  R  N  Q  R  K  T  V   pHDMHgpm2.seq
2444  ATC ATG ATC CAG AAG GGC AAC TTC CGC AAC CAG CGC AAG ACC GTG

                                1980
1962  K  C  F  N  C  G  K  E  G  H  I  A  K  N  C   NL4-3 genbank.SEQ
1962  AAG TGT TTC AAT TGT GGC AAA GAA GGG CAC ATA GCC AAA AAT TGC
2489  K  C  F  N  C  G  K  E  G  H  I  A  K  N  C   pHDMHgpm2.seq
2489  AAG TGC TTC AAC TGC GGC AAG GAG GGC CAC ATC GCC AAG AAC TGC

      2010                                    2040
2007  R  A  P  R  K  K  G  C  W  K  C  G  K  E  G   NL4-3 genbank.SEQ
2007  AGG GCC CCT AGG AAA AAG GGC TGT TGG AAA TGT GGA AAG GAA GGA
2534  R  A  P  R  K  K  G  C  W  K  C  G  K  E  G   pHDMHgpm2.seq
2534  CGC GCC CCC CGC AAG AAG GGC TGC TGG AAG TGC GGC AAG GAG GGC

                                2070
2052  H  Q  M  K  D  C  T  E  R  Q  A  N  F  L  G   NL4-3 genbank.SEQ
2052  CAC CAA ATG AAA GAT TGT ACT GAG AGA CAG GCT AAT TTT TTA GGG
2579  H  Q  M  K  D  C  T  E  R  Q  A  N  F  L  G   pHDMHgpm2.seq
2579  CAC CAG ATG AAA GAT TGT ACT GAG AGA CAG GCT AAT TTT TTA GGG

      2100                                    2130
2097  K  I  W  P  S  H  K  G  R  P  G  N  F  L  Q   NL4-3 genbank.SEQ
2097  AAG ATC TGG CCT TCC CAC AAG GGA AGG CCA GGG AAT TTT CTT CAG
2624  K  I  W  P  S  H  K  G  R  P  G  N  F  L  Q   pHDMHgpm2.seq
2624  AAG ATC TGG CCT TCC CAC AAG GGA AGG CCA GGG AAT TTT CTT CAG

                                2160
2142  S  R  P  E  P  T  A  P  P  E  E  S  F  R  F   NL4-3 genbank.SEQ
2142  AGC AGA CCA GAG CCA ACA GCC CCA CCA GAA GAG AGC TTC AGG TTT
2669  S  R  P  E  P  T  A  P  P  E  E  S  F  R  F   pHDMHgpm2.seq
2669  AGC AGA CCA GAG CCA ACA GCC CCA CCA GAA GAG AGC TTC AGG TTT

      2190                                    2220
2187  G  E  E  T  T  T  P  S  Q  K  Q  E  P  I  D   NL4-3 genbank.SEQ
2187  GGG GAA GAG ACA ACA ACT CCC TCT CAG AAG CAG GAG CCG ATA GAC
2714  G  E  E  T  T  T  P  S  Q  K  Q  E  P  I  D   pHDMHgpm2.seq
2714  GGG GAA GAG ACA ACA ACT CCC TCT CAG AAG CAG GAG CCG ATA GAC
```

Fig. 8D

Alignment Report of Codon optimization (gag).MEG, using Clustal method with PAM250 residue weight table.

```
                                    2250
2232  K   E   L   Y   P   L   A   S   L   R   S   L   F   G   S   NL4-3 genbank.SEQ
2232  AAG GAA CTG TAT CCT TTA GCT TCC CTC AGA TCA CTC TTT GGC AGC
2759  K   E   L   Y   P   L   A   S   L   R   S   L   F   G   S   pHDMHgpm2.seq
2759  AAG GAA CTG TAT CCT TTA GCT TCC CTC AGA TCA CTC TTT GGC AGC

      2280
2277  D   P   S   S   Q   .                                       NL4-3 genbank.SEQ
2277  GAC CCC TCG TCA CAA TAA
2804  D   P   S   S   Q   .                                       pHDMHgpm2.seq
2804  GAC CCC TCG TCA CAA TAA
```

Fig. 8E

Alignment Report of Codon Optimization (pol).MEG, using Clustal method with PAM250 residue weight table.

```
                2090                                                2120
2087  F  F  R  E  D  L  A  F  P  Q  G  K  A  R  E   NL4-3 genbank.SEQ
2087  TTT TTT AGG GAA GAT CTG GCC TTC CCA CAA GGG AAG GCC AGG GAA
2085  F  F  R  E  D  L  A  F  P  Q  G  K  A  R  E   pNL4-3.seq
2085  TTT TTT AGG GAA GAT CTG GCC TTC CCA CAA GGG AAG GCC AGG GAA
2612  F  F  R  E  D  L  A  F  P  Q  G  K  A  R  E   pHDMHgpm2.seq
2612  TTT TTT AGG GAA GAT CTG GCC TTC CCA CAA GGG AAG GCC AGG GAA

                          2150
2132  F  S  S  E  Q  T  R  A  N  S  P  T  R  R  E   NL4-3 genbank.SEQ
2132  TTT TCT TCA GAG CAG ACC AGA GCC AAC AGC CCC ACC AGA AGA GAG
2130  F  S  S  E  Q  T  R  A  N  S  P  T  R  R  E   pNL4-3.seq
2130  TTT TCT TCA GAG CAG ACC AGA GCC AAC AGC CCC ACC AGA AGA GAG
2657  F  S  S  E  Q  T  R  A  N  S  P  T  R  R  E   pHDMHgpm2.seq
2657  TTT TCT TCA GAG CAG ACC AGA GCC AAC AGC CCC ACC AGA AGA GAG

                2180                                                2210
2177  L  Q  V  W  G  R  D  N  N  S  L  S  E  A  G   NL4-3 genbank.SEQ
2177  CTT CAG GTT TGG GGA AGA GAC AAC AAC TCC CTC TCA GAA GCA GGA
2175  L  Q  V  W  G  R  D  N  N  S  L  S  E  A  G   pNL4-3.seq
2175  CTT CAG GTT TGG GGA AGA GAC AAC AAC TCC CTC TCA GAA GCA GGA
2702  L  Q  V  W  G  R  D  N  N  S  L  S  E  A  G   pHDMHgpm2.seq
2702  CTT CAG GTT TGG GGA AGA GAC AAC AAC TCC CTC TCA GAA GCA GGA

                          2240
2222  A  D  R  Q  G  T  V  S  F  S  F  P  Q  I  T   NL4-3 genbank.SEQ
2222  GCC GAT AGA CAA GGA ACT GTA TCC TTT AGC TTC CCT CAG ATC ACT
2220  A  D  R  Q  G  T  V  S  F  S  F  P  Q  I  T   pNL4-3.seq
2220  GCC GAT AGA CAA GGA ACT GTA TCC TTT AGC TTC CCT CAG ATC ACT
2747  A  D  R  Q  G  T  V  S  F  S  F  P  Q  I  T   pHDMHgpm2.seq
2747  GCC GAT AGA CAA GGA ACT GTA TCC TTT AGC TTC CCT CAG ATC ACT

                2270                                                2300
2267  L  W  Q  R  P  L  V  T  I  K  I  G  G  Q  L   NL4-3 genbank.SEQ
2267  CTT TGG CAG CGA CCC CTC GTC ACA ATA AAG ATA GGG GGG CAA TTA
2265  L  W  Q  R  P  L  V  T  I  K  I  G  G  Q  L   pNL4-3.seq
2265  CTT TGG CAG CGA CCC CTC GTC ACA ATA AAG ATA GGG GGG CAA TTA
2792  L  W  Q  R  P  L  V  T  I  K  I  G  G  Q  L   pHDMHgpm2.seq
2792  CTT TGG CAG CGA CCC CTC GTC ACA ATA AAG ATC GGT GGC CAG CTG

                          2330
2312  K  E  A  L  L  D  T  G  A  D  D  T  V  L  E   NL4-3 genbank.SEQ
2312  AAG GAA GCT CTA TTA GAT ACA GGA GCA GAT GAT ACA GTA TTA GAA
2310  K  E  A  L  L  D  T  G  A  D  D  T  V  L  E   pNL4-3.seq
2310  AAG GAA GCT CTA TTA GAT ACA GGA GCA GAT GAT ACA GTA TTA GAA
2837  K  E  A  L  L  D  T  G  A  D  D  T  V  L  E   pHDMHgpm2.seq
2837  AAG GAG GCC CTG CTG GAC ACC GGC GCC GAC GAC ACC GTG CTG GAG
```

Fig. 9A

Alignment Report of Codon Optimization (pol).MEG, using Clustal method with PAM250 residue weight table.

```
                2360                                                2390
2357  E  M  N  L  P  G  R  W  K  P  K  M  I  G  G  NL4-3 genbank.SEQ
2357  GAA ATG AAT TTG CCA GGA AGA TGG AAA CCA AAA ATG ATA GGG GGA
2355  E  M  N  L  P  G  R  W  K  P  K  M  I  G  G  pNL4-3.seq
2355  GAA ATG AAT TTG CCA GGA AGA TGG AAA CCA AAA ATG ATA GGG GGA
2882  E  M  N  L  P  G  R  W  K  P  K  M  I  G  G  pHDMHgpm2.seq
2882  GAG ATG AAC CTG CCC GGC CGC TGG AAG CCC AAG ATG ATC GGC GGC

                          2420
2402  I  G  G  F  I  K  V  G  Q  Y  D  Q  I  L  I  NL4-3 genbank.SEQ
2402  ATT GGA GGT TTT ATC AAA GTA GGA CAG TAT GAT CAG ATA CTC ATA
2400  I  G  G  F  I  K  V  R  Q  Y  D  Q  I  L  I  pNL4-3.seq
2400  ATT GGA GGT TTT ATC AAA GTA AGA CAG TAT GAT CAG ATA CTC ATA
2927  I  G  G  F  I  K  V  R  Q  Y  D  Q  I  L  I  pHDMHgpm2.seq
2927  ATC GGC GGC TTC ATC AAA GTC CGC CAG TAC GAC CAG ATC CTG ATC

          2450                                                2480
2447  E  I  C  G  H  K  A  I  G  T  V  L  V  G  P  NL4-3 genbank.SEQ
2447  GAA ATC TGC GGA CAT AAA GCT ATA GGT ACA GTA TTA GTA GGA CCT
2445  E  I  C  G  H  K  A  I  G  T  V  L  V  G  P  pNL4-3.seq
2445  GAA ATC TGC GGA CAT AAA GCT ATA GGT ACA GTA TTA GTA GGA CCT
2972  E  I  C  G  H  K  A  I  G  T  V  L  V  G  P  pHDMHgpm2.seq
2972  GAG ATC TGC GGC CAC AAG GCC ATC GGC ACC GTG CTG GTG GGC CCC

                          2510
2492  T  P  V  N  I  I  G  R  N  L  L  T  Q  I  G  NL4-3 genbank.SEQ
2492  ACA CCT GTC AAC ATA ATT GGA AGA AAT CTG TTG ACT CAG ATT GGC
2490  T  P  V  N  I  I  G  R  N  L  L  T  Q  I  G  pNL4-3.seq
2490  ACA CCT GTC AAC ATA ATT GGA AGA AAT CTG TTG ACT CAG ATT GGC
3017  T  P  V  N  I  I  G  R  N  L  L  T  Q  I  G  pHDMHgpm2.seq
3017  ACC CCC GTG AAC ATC ATC GGC CGC AAC CTG CTG ACC CAG ATC GGC

          2540                                                2570
2537  C  T  L  N  F  P  I  S  P  I  E  T  V  P  V  NL4-3 genbank.SEQ
2537  TGC ACT TTA AAT TTT CCC ATT AGT CCT ATT GAG ACT GTA CCA GTA
2535  C  T  L  N  F  P  I  S  P  I  E  T  V  P  V  pNL4-3.seq
2535  TGC ACT TTA AAT TTT CCC ATT AGT CCT ATT GAG ACT GTA CCA GTA
3062  C  T  L  N  F  P  I  S  P  I  E  T  V  P  V  pHDMHgpm2.seq
3062  TGC ACC CTG AAC TTC CCC ATC TCC CCC ATC GAG ACC GTG CCC GTG

                          2600
2582  K  L  K  P  G  M  D  G  P  K  V  K  Q  W  P  NL4-3 genbank.SEQ
2582  AAA TTA AAG CCA GGA ATG GAT GGC CCA AAA GTT AAA CAA TGG CCA
2580  K  L  K  P  G  M  D  G  P  K  V  K  Q  W  P  pNL4-3.seq
2580  AAA TTA AAG CCA GGA ATG GAT GGC CCA AAA GTT AAA CAA TGG CCA
3107  K  L  K  P  G  M  D  G  P  K  V  K  Q  W  P  pHDMHgpm2.seq
3107  AAG CTG AAG CCC GGC ATG GAC GGC CCC AAA GTC AAG CAG TGG CCC
```

Fig. 9B

Alignment Report of Codon Optimization (pol).MEG, using Clustal method with PAM250 residue weight table.

```
                2630                                                2660
2627  L  T  E  E  K  I  K  A  L  V  E  I  C  T  E   NL4-3 genbank.SEQ
2627  TTG ACA GAA GAA AAA ATA AAA GCA TTA GTA GAA ATT TGT ACA GAA
2625  L  T  E  E  K  I  K  A  L  V  E  I  C  T  E   pNL4-3.seq
2625  TTG ACA GAA GAA AAA ATA AAA GCA TTA GTA GAA ATT TGT ACA GAA
3152  L  T  E  E  K  I  K  A  L  V  E  I  C  T  E   pHDMHgpm2.seq
3152  CTG ACC GAG GAG AAG ATC AAG GCC CTG GTG GAG ATC TGC ACC GAG

                                    2690
2672  M  E  K  E  G  K  I  S  K  I  G  P  E  N  P   NL4-3 genbank.SEQ
2672  ATG GAA AAG GAA GGA AAA ATT TCA AAA ATT GGG CCT GAA AAT CCA
2670  M  E  K  E  G  K  I  S  K  I  G  P  E  N  P   pNL4-3.seq
2670  ATG GAA AAG GAA GGA AAA ATT TCA AAA ATT GGG CCT GAA AAT CCA
3197  M  E  K  E  G  K  I  S  K  I  G  P  E  N  P   pHDMHgpm2.seq
3197  ATG GAG AAG GAG GGC AAG ATC TCC AAG ATC GGC CCC GAG AAC CCC

                2720                                                2750
2717  Y  N  T  P  V  F  A  I  K  K  K  D  S  T  K   NL4-3 genbank.SEQ
2717  TAC AAT ACT CCA GTA TTT GCC ATA AAG AAA AAA GAC AGT ACT AAA
2715  Y  N  T  P  V  F  A  I  K  K  K  D  S  T  K   pNL4-3.seq
2715  TAC AAT ACT CCA GTA TTT GCC ATA AAG AAA AAA GAC AGT ACT AAA
3242  Y  N  T  P  V  F  A  I  K  K  K  D  S  T  K   pHDMHgpm2.seq
3242  TAC AAC ACC CCC GTG TTC GCC ATC AAG AAG AAG GAC TCC ACC AAG

                                    2780
2762  W  R  K  L  V  D  F  R  E  L  N  K  R  T  Q   NL4-3 genbank.SEQ
2762  TGG AGA AAA TTA GTA GAT TTC AGA GAA CTT AAT AAG AGA ACT CAA
2760  W  R  K  L  V  D  F  R  E  L  N  K  R  T  Q   pNL4-3.seq
2760  TGG AGA AAA TTA GTA GAT TTC AGA GAA CTT AAT AAG AGA ACT CAA
3287  W  R  K  L  V  D  F  R  E  L  N  K  R  T  Q   pHDMHgpm2.seq
3287  TGG CGC AAG CTG GTG GAC TTC CGC GAG CTG AAC AAG CGC ACC CAG

                2810                                                2840
2807  D  F  W  E  V  Q  L  G  I  P  H  P  A  G  L   NL4-3 genbank.SEQ
2807  GAT TTC TGG GAA GTT CAA TTA GGA ATA CCA CAT CCT GCA GGG TTA
2805  D  F  W  E  V  Q  L  G  I  P  H  P  A  G  L   pNL4-3.seq
2805  GAT TTC TGG GAA GTT CAA TTA GGA ATA CCA CAT CCT GCA GGG TTA
3332  D  F  W  E  V  Q  L  G  I  P  H  P  A  G  L   pHDMHgpm2.seq
3332  GAC TTC TGG GAG GTG CAG CTG GGC ATC CCC CAC CCC GCC GGC CTG

                                    2870
2852  K  Q  K  K  S  V  T  V  L  D  V  G  D  A  Y   NL4-3 genbank.SEQ
2852  AAA CAG AAA AAA TCA GTA ACA GTA CTG GAT GTG GGC GAT GCA TAT
2850  K  Q  K  K  S  V  T  V  L  D  V  G  D  A  Y   pNL4-3.seq
2850  AAA CAG AAA AAA TCA GTA ACA GTA CTG GAT GTG GGC GAT GCA TAT
3377  K  Q  K  K  S  V  T  V  L  D  V  G  D  A  Y   pHDMHgpm2.seq
3377  AAG CAG AAG AAG TCC GTG ACC GTG CTG GAC GTG GGC GAC GCC TAC
```

Fig. 9C

Alignment Report of Codon Optimization (pol).MEG, using Clustal method with PAM250 residue weight table.

```
                2900                                                2930
2897  F  S  V  P  L  D  K  D  F  R  K  Y  T  A  F  NL4-3 genbank.SEQ
2897  TTT TCA GTT CCC TTA GAT AAA GAC TTC AGG AAG TAT ACT GCA TTT
2895  F  S  V  P  L  D  K  D  F  R  K  Y  T  A  F  pNL4-3.seq
2895  TTT TCA GTT CCC TTA GAT AAA GAC TTC AGG AAG TAT ACT GCA TTT
3422  F  S  V  P  L  D  K  D  F  R  K  Y  T  A  F  pHDMHgpm2.seq
3422  TTC TCC GTG CCC CTG GAC AAG GAC TTC CGC AAG TAC ACC GCC TTC

                                2960
2942  T  I  P  S  I  N  N  E  T  P  G  I  R  Y  Q  NL4-3 genbank.SEQ
2942  ACC ATA CCT AGT ATA AAC AAT GAG ACA CCA GGG ATT AGA TAT CAG
2940  T  I  P  S  I  N  N  E  T  P  G  I  R  Y  Q  pNL4-3.seq
2940  ACC ATA CCT AGT ATA AAC AAT GAG ACA CCA GGG ATT AGA TAT CAG
3467  T  I  P  S  I  N  N  E  T  P  G  I  R  Y  Q  pHDMHgpm2.seq
3467  ACC ATC CCC TCC ATC AAC AAC GAG ACC CCC GGC ATC CGC TAC CAG

      2990                                                3020
2987  Y  N  V  L  P  Q  G  W  K  G  S  P  A  I  F  NL4-3 genbank.SEQ
2987  TAC AAT GTG CTT CCA CAG GGA TGG AAA GGA TCA CCA GCA ATA TTC
2985  Y  N  V  L  P  Q  G  W  K  G  S  P  A  I  F  pNL4-3.seq
2985  TAC AAT GTG CTT CCA CAG GGA TGG AAA GGA TCA CCA GCA ATA TTC
3512  Y  N  V  L  P  Q  G  W  K  G  S  P  A  I  F  pHDMHgpm2.seq
3512  TAC AAC GTG CTG CCC CAG GGC TGG AAG GGC TCC CCC GCC ATC TTC

                3050
3032  Q  C  S  M  T  K  I  L  E  P  F  R  K  Q  N  NL4-3 genbank.SEQ
3032  CAG TGT AGC ATG ACA AAA ATC TTA GAG CCT TTT AGA AAA CAA AAT
3030  Q  C  S  M  T  K  I  L  E  P  F  R  K  Q  N  pNL4-3.seq
3030  CAG TGT AGC ATG ACA AAA ATC TTA GAG CCT TTT AGA AAA CAA AAT
3557  Q  C  S  M  T  K  I  L  E  P  F  R  K  Q  N  pHDMHgpm2.seq
3557  CAG TGC TCC ATG ACC AAG ATC CTG GAG CCC TTC CGC AAG CAG AAC

      3080                                                3110
3077  P  D  I  V  I  Y  Q  Y  M  D  D  L  Y  V  G  NL4-3 genbank.SEQ
3077  CCA GAC ATA GTC ATC TAT CAA TAC ATG GAT GAT TTG TAT GTA GGA
3075  P  D  I  V  I  Y  Q  Y  M  D  D  L  Y  V  G  pNL4-3.seq
3075  CCA GAC ATA GTC ATC TAT CAA TAC ATG GAT GAT TTG TAT GTA GGA
3602  P  D  I  V  I  Y  Q  Y  M  D  D  L  Y  V  G  pHDMHgpm2.seq
3602  CCC GAC ATC GTG ATC TAC CAG TAC ATG GAC GAC CTG TAC GTG GGC

                3140
3122  S  D  L  E  I  G  Q  H  R  T  K  I  E  E  L  NL4-3 genbank.SEQ
3122  TCT GAC TTA GAA ATA GGG CAG CAT AGA ACA AAA ATA GAG GAA CTG
3120  S  D  L  E  I  G  Q  H  R  T  K  I  E  E  L  pNL4-3.seq
3120  TCT GAC TTA GAA ATA GGG CAG CAT AGA ACA AAA ATA GAG GAA CTG
3647  S  D  L  E  I  G  Q  H  R  T  K  I  E  E  L  pHDMHgpm2.seq
3647  TCC GAC CTG GAG ATC GGC CAG CAC CGG ACC AAG ATC GAG GAG CTG
```

Fig. 9D

Alignment Report of Codon Optimization (pol).MEG, using Clustal method with PAM250 residue weight table.

```
                3170                                                3200
3167  R  Q  H  L  L  R  W  G  F  T  T  P  D  K  K   NL4-3 genbank.SEQ
3167  AGA CAA CAT CTG TTG AGG TGG GGA TTT ACC ACA CCA GAC AAA AAA
3165  R  Q  H  L  L  R  W  G  F  T  T  P  D  K  K   pNL4-3.seq
3165  AGA CAA CAT CTG TTG AGG TGG GGA TTT ACC ACA CCA GAC AAA AAA
3692  R  Q  H  L  L  R  W  G  F  T  T  P  D  K  K   pHDMHgpm2.seq
3692  CGC CAG CAC CTG CTG CGC TGG GGC TTC ACC ACC CCC GAC AAG AAG

                                3230
3212  H  Q  K  E  P  P  F  L  W  M  G  Y  E  L  H   NL4-3 genbank.SEQ
3212  CAT CAG AAA GAA CCT CCA TTC CTT TGG ATG GGT TAT GAA CTC CAT
3210  H  Q  K  E  P  P  F  L  W  M  G  Y  E  L  H   pNL4-3.seq
3210  CAT CAG AAA GAA CCT CCA TTC CTT TGG ATG GGT TAT GAA CTC CAT
3737  H  Q  K  E  P  P  F  L  W  M  G  Y  E  L  H   pHDMHgpm2.seq
3737  CAC CAG AAG GAG CCC CCC TTC CTG TGG ATG GGC TAC GAG CTG CAC

                3260                                3290
3257  P  D  K  W  T  V  Q  P  I  V  L  P  E  K  D   NL4-3 genbank.SEQ
3257  CCT GAT AAA TGG ACA GTA CAG CCT ATA GTG CTG CCA GAA AAG GAC
3255  P  D  K  W  T  V  Q  P  I  V  L  P  E  K  D   pNL4-3.seq
3255  CCT GAT AAA TGG ACA GTA CAG CCT ATA GTG CTG CCA GAA AAG GAC
3782  P  D  K  W  T  V  Q  P  I  V  L  P  E  K  D   pHDMHgpm2.seq
3782  CCC GAC AAG TGG ACC GTG CAG CCC ATC GTG CTG CCC GAG AAG GAC

                                3320
3302  S  W  T  V  N  D  I  Q  K  L  V  G  K  L  N   NL4-3 genbank.SEQ
3302  AGC TGG ACT GTC AAT GAC ATA CAG AAA TTA GTG GGA AAA TTG AAT
3300  S  W  T  V  N  D  I  Q  K  L  V  G  K  L  N   pNL4-3.seq
3300  AGC TGG ACT GTC AAT GAC ATA CAG AAA TTA GTG GGA AAA TTG AAT
3827  S  W  T  V  N  D  I  Q  K  L  V  G  K  L  N   pHDMHgpm2.seq
3827  TCC TGG ACC GTG AAC GAC ATC CAG AAG CTG GTG GGC AAG CTG AAC

                3350                                3380
3347  W  A  S  Q  I  Y  A  G  I  K  V  R  Q  L  C   NL4-3 genbank.SEQ
3347  TGG GCA AGT CAG ATT TAT GCA GGG ATT AAA GTA AGG CAA TTA TGT
3345  W  A  S  Q  I  Y  A  G  I  K  V  R  Q  L  C   pNL4-3.seq
3345  TGG GCA AGT CAG ATT TAT GCA GGG ATT AAA GTA AGG CAA TTA TGT
3872  W  A  S  Q  I  Y  A  G  I  K  V  R  Q  L  C   pHDMHgpm2.seq
3872  TGG GCC TCC CAG ATC TAC GCC GGC ATC AAA GTC CGC CAG CTG TGC

                                3410
3392  K  L  L  R  G  T  K  A  L  T  E  V  V  P  L   NL4-3 genbank.SEQ
3392  AAA CTT CTT AGG GGA ACC AAA GCA CTA ACA GAA GTA GTA CCA CTA
3390  K  L  L  R  G  T  K  A  L  T  E  V  V  P  L   pNL4-3.seq
3390  AAA CTT CTT AGG GGA ACC AAA GCA CTA ACA GAA GTA GTA CCA CTA
3917  K  L  L  R  G  T  K  A  L  T  E  V  V  P  L   pHDMHgpm2.seq
3917  AAG CTG CTG CGC GGC ACC AAG GCC CTG ACC GAG GTG GTG CCC CTG
```

Fig. 9E

Alignment Report of Codon Optimization (pol).MEG, using Clustal method with PAM250 residue weight table.

```
                3440                                                3470
3437  T  E  E  A  E  L  E  L  A  E  N  R  E  I  L  NL4-3 genbank.SEQ
3437 ACA GAA GAA GCA GAG CTA GAA CTG GCA GAA AAC AGG GAG ATT CTA
3435  T  E  E  A  E  L  E  L  A  E  N  R  E  I  L  pNL4-3.seq_
3435 ACA GAA GAA GCA GAG CTA GAA CTG GCA GAA AAC AGG GAG ATT CTA
3962  T  E  E  A  E  L  E  L  A  E  N  R  E  I  L  pHDMHgpm2.seq
3962 ACC GAG GAG GCC GAG CTG GAG CTG GCC GAG AAC CGC GAG ATC CTG

                          3500
3482  K  E  P  V  H  G  V  Y  Y  D  P  S  K  D  L  NL4-3 genbank.SEQ
3482 AAA GAA CCG GTA CAT GGA GTG TAT TAT GAC CCA TCA AAA GAC TTA
3480  K  E  P  V  H  G  V  Y  Y  D  P  S  K  D  L  pNL4-3.seq
3480 AAA GAA CCG GTA CAT GGA GTG TAT TAT GAC CCA TCA AAA GAC TTA
4007  K  E  P  V  H  G  V  Y  Y  D  P  S  K  D  L  pHDMHgpm2.seq
4007 AAG GAG CCC GTG CAC GGC GTG TAC TAC GAC CCC TCC AAG GAC CTG

                3530                                                3560
3527  I  A  E  I  Q  K  Q  G  Q  G  Q  W  T  Y  Q  NL4-3 genbank.SEQ
3527 ATA GCA GAA ATA CAG AAG CAG GGG CAA GGC CAA TGG ACA TAT CAA
3525  I  A  E  I  Q  K  Q  G  Q  G  Q  W  T  Y  Q  pNL4-3.seq
3525 ATA GCA GAA ATA CAG AAG CAG GGG CAA GGC CAA TGG ACA TAT CAA
4052  I  A  E  I  Q  K  Q  G  Q  G  Q  W  T  Y  Q  pHDMHgpm2.seq
4052 ATC GCC GAG ATC CAG AAG CAG GGC CAG GGC CAG TGG ACC TAC CAG

                          3590
3572  I  Y  Q  E  P  F  K  N  L  K  T  G  K  Y  A  NL4-3 genbank.SEQ
3572 ATT TAT CAA GAG CCA TTT AAA AAT CTG AAA ACA GGA AAA TAT GCA
3570  I  Y  Q  E  P  F  K  N  L  K  T  G  K  Y  A  pNL4-3.seq
3570 ATT TAT CAA GAG CCA TTT AAA AAT CTG AAA ACA GGA AAA TAT GCA
4097  I  Y  Q  E  P  F  K  N  L  K  T  G  K  Y  A  pHDMHgpm2.seq
4097 ATC TAC CAG GAG CCC TTC AAG AAC CTG AAG ACC GGC AAA TAC GCC

                3620                                                3650
3617  R  M  K  G  A  H  T  N  D  V  K  Q  L  T  E  NL4-3 genbank.SEQ
3617 AGA ATG AAG GGT GCC CAC ACT AAT GAT GTG AAA CAA TTA ACA GAG
3615  R  M  K  G  A  H  T  N  D  V  K  Q  L  T  E  pNL4-3.seq
3615 AGA ATG AAG GGT GCC CAC ACT AAT GAT GTG AAA CAA TTA ACA GAG
4142  R  M  K  G  A  H  T  N  D  V  K  Q  L  T  E  pHDMHgpm2.seq
4142 CGC ATG AAG GGC GCC CAC ACC AAC GAC GTG AAG CAG CTG ACC GAG

                          3680
3662  A  V  Q  K  I  A  T  E  S  I  V  I  W  G  K  NL4-3 genbank.SEQ
3662 GCA GTA CAA AAA ATA GCC ACA GAA AGC ATA GTA ATA TGG GGA AAG
3660  A  V  Q  K  I  A  T  E  S  I  V  I  W  G  K  pNL4-3.seq
3660 GCA GTA CAA AAA ATA GCC ACA GAA AGC ATA GTA ATA TGG GGA AAG
4187  A  V  Q  K  I  A  T  E  S  I  V  I  W  G  K  pHDMHgpm2.seq
4187 GCC GTG CAG AAG ATC GCC ACC GAG TCC ATC GTG ATC TGG GGC AAG
```

Fig. 9F

Alignment Report of Codon Optimization (pol).MEG, using Clustal method with PAM250 residue weight table.

```
                3710                                                3740
3707  T  P  K  F  K  L  P  I  Q  K  E  T  W  E  A  NL4-3 genbank.SEQ
3707  ACT CCT AAA TTT AAA TTA CCC ATA CAA AAG GAA ACA TGG GAA GCA
3705  T  P  K  F  K  L  P  I  Q  K  E  T  W  E  A  pNL4-3.seq
3705  ACT CCT AAA TTT AAA TTA CCC ATA CAA AAG GAA ACA TGG GAA GCA
4232  T  P  K  F  K  L  P  I  Q  K  E  T  W  E  A  pHDMHgpm2.seq
4232  ACT CCC AAG TTC AAG CTG CCC ATC CAG AAG GAG ACC TGG GAG GCC

                                    3770
3752  W  W  T  E  Y  W  Q  A  T  W  I  P  E  W  E  NL4-3 genbank.SEQ
3752  TGG TGG ACA GAG TAT TGG CAA GCC ACC TGG ATT CCT GAG TGG GAG
3750  W  W  T  E  Y  W  Q  A  T  W  I  P  E  W  E  pNL4-3.seq
3750  TGG TGG ACA GAG TAT TGG CAA GCC ACC TGG ATT CCT GAG TGG GAG
4277  W  W  T  E  Y  W  Q  A  T  W  I  P  E  W  E  pHDMHgpm2.seq
4277  TGG TGG ACC GAG TAC TGG CAG GCC ACC TGG ATC CCC GAG TGG GAG

                3800                                                3830
3797  F  V  N  T  P  P  L  V  K  L  W  Y  Q  L  E  NL4-3 genbank.SEQ
3797  TTT GTC AAT ACC CCT CCC TTA GTG AAG TTA TGG TAC CAG TTA GAG
3795  F  V  N  T  P  P  L  V  K  L  W  Y  Q  L  E  pNL4-3.seq
3795  TTT GTC AAT ACC CCT CCC TTA GTG AAG TTA TGG TAC CAG TTA GAG
4322  F  V  N  T  P  P  L  V  K  L  W  Y  Q  L  E  pHDMHgpm2.seq
4322  TTC GTG AAC ACC CCC CCC CTG GTG AAG CTG TGG TAC CAG CTG GAG

                                    3860
3842  K  E  P  I  I  G  A  E  T  F  Y  V  D  G  A  NL4-3 genbank.SEQ
3842  AAA GAA CCC ATA ATA GGA GCA GAA ACT TTC TAT GTA GAT GGG GCA
3840  K  E  P  I  I  G  A  E  T  F  Y  V  D  G  A  pNL4-3.seq
3840  AAA GAA CCC ATA ATA GGA GCA GAA ACT TTC TAT GTA GAT GGG GCA
4367  K  E  P  I  I  G  A  E  T  F  Y  V  D  G  A  pHDMHgpm2.seq
4367  AAG GAG CCC ATC ATC GGC GCC GAG ACC TTC TAC GTG GAC GGC GCC

                3890                                                3920
3887  A  N  R  E  T  K  L  G  K  A  G  Y  V  T  D  NL4-3 genbank.SEQ
3887  GCC AAT AGG GAA ACT AAA TTA GGA AAA GCA GGA TAT GTA ACT GAC
3885  A  N  R  E  T  K  L  G  K  A  G  Y  V  T  D  pNL4-3.seq
3885  GCC AAT AGG GAA ACT AAA TTA GGA AAA GCA GGA TAT GTA ACT GAC
4412  A  N  R  E  T  K  L  G  K  A  G  Y  V  T  D  pHDMHgpm2.seq
4412  GCC AAC CGC GAG ACC AAG CTG GGC AAG GCC GGC TAC GTG ACC GAC

                                    3950
3932  R  G  R  Q  K  V  V  P  L  T  D  T  T  N  Q  NL4-3 genbank.SEQ
3932  AGA GGA AGA CAA AAA GTT GTC CCC CTA ACG GAC ACA ACA AAT CAG
3930  R  G  R  Q  K  V  V  P  L  T  D  T  T  N  Q  pNL4-3.seq
3930  AGA GGA AGA CAA AAA GTT GTC CCC CTA ACG GAC ACA ACA AAT CAG
4457  R  G  R  Q  K  V  V  P  L  T  D  T  T  N  Q  pHDMHgpm2.seq
4457  CGC GGC CGC CAG AAG GTG GTG CCC CTG ACC GAC ACC ACC AAC CAG
```

Fig. 9G

Alignment Report of Codon Optimization (pol).MEG, using Clustal method with PAM250 residue weight table.

```
                3980                                                4010
3977  K  T  E  L  Q  A  I  H  L  A  L  Q  D  S  G   NL4-3 genbank.SEQ
3977 AAG ACT GAG TTA CAA GCA ATT CAT CTA GCT TTG CAG GAT TCG GGA
3975  K  T  E  L  Q  A  I  H  L  A  L  Q  D  S  G   pNL4-3.seq
3975 AAG ACT GAG TTA CAA GCA ATT CAT CTA GCT TTG CAG GAT TCG GGA
4502  K  T  E  L  Q  A  I  H  L  A  L  Q  D  S  G   pHDMHgpm2.seq
4502 AAG ACC GAG CTG CAG GCC ATC CAC CTG GCC CTG CAA GAC TCC GGC

                        4040
4022  L  E  V  N  I  V  T  D  S  Q  Y  A  L  G  I   NL4-3 genbank.SEQ
4022 TTA GAA GTA AAC ATA GTG ACA GAC TCA CAA TAT GCA TTG GGA ATC
4020  L  E  V  N  I  V  T  D  S  Q  Y  A  L  G  I   pNL4-3.seq
4020 TTA GAA GTA AAC ATA GTG ACA GAC TCA CAA TAT GCA TTG GGA ATC
4547  L  E  V  N  I  V  T  D  S  Q  Y  A  L  G  I   pHDMHgpm2.seq
4547 CTG GAG GTG AAC ATC GTG ACC GAC TCC CAG TAT GCA TTG GGC ATC

                4070                                        4100
4067  I  Q  A  Q  P  D  K  S  E  S  E  L  V  S  Q   NL4-3 genbank.SEQ
4067 ATT CAA GCA CAA CCA GAT AAG AGT GAA TCA GAG TTA GTC AGT CAA
4065  I  Q  A  Q  P  D  K  S  E  S  E  L  V  S  Q   pNL4-3.seq
4065 ATT CAA GCA CAA CCA GAT AAG AGT GAA TCA GAG TTA GTC AGT CAA
4592  I  Q  A  Q  P  D  K  S  E  S  E  L  V  S  Q   pHDMHgpm2.seq
4592 ATC CAG GCC CAG CCC GAC AAG TCC GAG TCC GAG CTG GTG TCC CAG

                        4130
4112  I  I  E  Q  L  I  K  K  E  K  V  Y  L  A  W   NL4-3 genbank.SEQ
4112 ATA ATA GAG CAG TTA ATA AAA AAG GAA AAA GTC TAC CTG GCA TGG
4110  I  I  E  Q  L  I  K  K  E  K  V  Y  L  A  W   pNL4-3.seq
4110 ATA ATA GAG CAG TTA ATA AAA AAG GAA AAA GTC TAC CTG GCA TGG
4637  I  I  E  Q  L  I  K  K  E  K  V  Y  L  A  W   pHDMHgpm2.seq
4637 ATC ATC GAG CAG CTG ATC AAG AAG GAG AAG GTG TAC CTG GCC TGG

                4160                                        4190
4157  V  P  A  H  K  G  I  G  G  N  E  Q  V  D  G   NL4-3 genbank.SEQ
4157 GTA CCA GCA CAC AAA GGA ATT GGA GGA AAT GAA CAA GTA GAT GGG
4155  V  P  A  H  K  G  I  G  G  N  E  Q  V  D  K   pNL4-3.seq
4155 GTA CCA GCA CAC AAA GGA ATT GGA GGA AAT GAA CAA GTA GAT AAG
4682  V  P  A  H  K  G  I  G  G  N  E  Q  V  D  K   pHDMHgpm2.seq
4682 GTG CCC GCC CAC AAG GGC ATC GGC GGC AAC GAG CAG GTG GAC AAG

                        4220
4202  L  V  S  A  G  I  R  K  V  L  F  L  D  G  I   NL4-3 genbank.SEQ
4202 TTG GTC AGT GCT GGA ATC AGG AAA GTA CTA TTT TTA GAT GGA ATA
4200  L  V  S  A  G  I  R  K  V  L  F  L  D  G  I   pNL4-3.seq
4200 TTG GTC AGT GCT GGA ATC AGG AAA GTA CTA TTT TTA GAT GGA ATA
4727  L  V  S  A  G  I  R  K  V  L  F  L  D  G  I   pHDMHgpm2.seq
4727 CTG GTG TCC GCC GGC ATC CGC AAG GTG CTG TTC CTG GAC GGC ATC
```

Fig. 9H

Alignment Report of Codon Optimization (pol).MEG, using Clustal method with PAM250 residue weight table.

```
                4250                                                4280
4247  D  K  A  Q  E  E  H  E  K  Y  H  S  N  W  R   NL4-3 genbank.SEQ
4247  GAT AAG GCC CAA GAA GAA CAT GAG AAA TAT CAC AGT AAT TGG AGA
4245  D  K  A  Q  E  E  H  E  K  Y  H  S  N  W  R   pNL4-3.seq
4245  GAT AAG GCC CAA GAA GAA CAT GAG AAA TAT CAC AGT AAT TGG AGA
4772  D  K  A  Q  E  E  H  E  K  Y  H  S  N  W  R   pHDMHgpm2.seq
4772  GAC AAG GCC CAG GAG GAG CAC GAG AAG TAC CAC TCC AAC TGG CGC

                          4310
4292  A  M  A  S  D  F  N  L  P  P  V  V  A  K  E   NL4-3 genbank.SEQ
4292  GCA ATG GCT AGT GAT TTT AAC CTA CCA CCT GTA GTA GCA AAA GAA
4290  A  M  A  S  D  F  N  L  P  P  V  V  A  K  E   pNL4-3.seq
4290  GCA ATG GCT AGT GAT TTT AAC CTA CCA CCT GTA GTA GCA AAA GAA
4817  A  M  A  S  D  F  N  L  P  P  V  V  A  K  E   pHDMHgpm2.seq
4817  GCC ATG GCC TCC GAC TTC AAC CTG CCC CCC GTG GTG GCC AAG GAG

                4340                                                4370
4337  I  V  A  S  C  D  K  C  Q  L  K  G  E  A  M   NL4-3 genbank.SEQ
4337  ATA GTA GCC AGC TGT GAT AAA TGT CAG CTA AAA GGG GAA GCC ATG
4335  I  V  A  S  C  D  K  C  Q  L  K  G  E  A  M   pNL4-3.seq
4335  ATA GTA GCC AGC TGT GAT AAA TGT CAG CTA AAA GGG GAA GCC ATG
4862  I  V  A  S  C  D  K  C  Q  L  K  G  E  A  M   pHDMHgpm2.seq
4862  ATC GTG GCC TCC TGC GAC AAG TGC CAG CTG AAG GGC GAG GCC ATG

                          4400
4382  H  G  Q  V  D  C  S  P  G  I  W  Q  L  D  C   NL4-3 genbank.SEQ
4382  CAT GGA CAA GTA GAC TGT AGC CCA GGA ATA TGG CAG CTA GAT TGT
4380  H  G  Q  V  D  C  S  P  G  I  W  Q  L  D  C   pNL4-3.seq
4380  CAT GGA CAA GTA GAC TGT AGC CCA GGA ATA TGG CAG CTA GAT TGT
4907  H  G  Q  V  D  C  S  P  G  I  W  Q  L  D  C   pHDMHgpm2.seq
4907  CAC GGC CAG GTG GAC TGC TCC CCC GGC ATC TGG CAG CTG GAC TGC

                4430                                                4460
4427  T  H  L  E  G  K  V  I  L  V  A  V  H  V  A   NL4-3 genbank.SEQ
4427  ACA CAT TTA GAA GGA AAA GTT ATC TTG GTA GCA GTT CAT GTA GCC
4425  T  H  L  E  G  K  V  I  L  V  A  V  H  V  A   pNL4-3.seq
4425  ACA CAT TTA GAA GGA AAA GTT ATC TTG GTA GCA GTT CAT GTA GCC
4952  T  H  L  E  G  K  V  I  L  V  A  V  H  V  A   pHDMHgpm2.seq
4952  ACC CAC CTG GAG GGC AAG GTG ATC CTG GTG GCC GTG CAC GTG GCC

                          4490
4472  S  G  Y  I  E  A  E  V  I  P  A  E  T  G  Q   NL4-3 genbank.SEQ
4472  AGT GGA TAT ATA GAA GCA GAA GTA ATT CCA GCA GAG ACA GGG CAA
4470  S  G  Y  I  E  A  E  V  I  P  A  E  T  G  Q   pNL4-3.seq
4470  AGT GGA TAT ATA GAA GCA GAA GTA ATT CCA GCA GAG ACA GGG CAA
4997  S  G  Y  I  E  A  E  V  I  P  A  E  T  G  Q   pHDMHgpm2.seq
4997  TCC GGC TAC ATC GAG GCC GAG GTG ATC CCC GCC GAG ACC GGC CAG
```

Fig. 9I

Alignment Report of Codon Optimization (pol).MEG, using Clustal method with PAM250 residue weight table.

```
                4520                                                4550
4517  E  T  A  Y  F  L  L  K  L  A  G  R  W  P  V   NL4-3 genbank.SEQ
4517 GAA ACA GCA TAC TTC CTC TTA AAA TTA GCA GGA AGA TGG CCA GTA
4515  E  T  A  Y  F  L  L  K  L  A  G  R  W  P  V   pNL4-3.seq
4515 GAA ACA GCA TAC TTC CTC TTA AAA TTA GCA GGA AGA TGG CCA GTA
5042  E  T  A  Y  F  L  L  K  L  A  G  R  W  P  V   pHDMHgpm2.seq
5042 GAG ACC GCC TAC TTC CTG CTG AAG CTG GCC GGC CGC TGG CCC GTG

                          4580
4562  K  T  V  H  T  D  N  G  S  N  F  T  S  T  T   NL4-3 genbank.SEQ
4562 AAA ACA GTA CAT ACA GAC AAT GGC AGC AAT TTC ACC AGT ACT ACA
4560  K  T  V  H  T  D  N  G  S  N  F  T  S  T  T   pNL4-3.seq
4560 AAA ACA GTA CAT ACA GAC AAT GGC AGC AAT TTC ACC AGT ACT ACA
5087  K  T  V  H  T  D  N  G  S  N  F  T  S  T  T   pHDMHgpm2.seq
5087 AAG ACC GTG CAC ACC GAC AAC GGC TCC AAC TTC ACC TCC ACC ACC

                4610                                                4640
4607  V  K  A  A  C  W  W  A  G  I  K  Q  E  F  G   NL4-3 genbank.SEQ
4607 GTT AAG GCC GCC TGT TGG TGG GCG GGG ATC AAG CAG GAA TTT GGC
4605  V  K  A  A  C  W  W  A  G  I  K  Q  E  F  G   pNL4-3.seq
4605 GTT AAG GCC GCC TGT TGG TGG GCG GGG ATC AAG CAG GAA TTT GGC
5132  V  K  A  A  C  W  W  A  G  I  K  Q  E  F  G   pHDMHgpm2.seq
5132 GTG AAG GCC GCC TGC TGG TGG GCC GGC ATC AAG CAG GAG TTC GGC

                          4670
4652  I  P  Y  N  P  Q  S  Q  G  V  I  E  S  M  N   NL4-3 genbank.SEQ
4652 ATT CCC TAC AAT CCC CAA AGT CAA GGA GTA ATA GAA TCT ATG AAT
4650  I  P  Y  N  P  Q  S  Q  G  V  I  E  S  M  N   pNL4-3.seq
4650 ATT CCC TAC AAT CCC CAA AGT CAA GGA GTA ATA GAA TCT ATG AAT
5177  I  P  Y  N  P  Q  S  Q  G  V  I  E  S  M  N   pHDMHgpm2.seq
5177 ATC CCC TAC AAC CCC CAG TCC CAG GGC GTG ATC GAG TCC ATG AAC

                4700                                                4730
4697  K  E  L  K  K  I  I  G  Q  V  R  D  Q  A  E   NL4-3 genbank.SEQ
4697 AAA GAA TTA AAG AAA ATT ATA GGA CAG GTA AGA GAT CAG GCT GAA
4695  K  E  L  K  K  I  I  G  Q  V  R  D  Q  A  E   pNL4-3.seq
4695 AAA GAA TTA AAG AAA ATT ATA GGA CAG GTA AGA GAT CAG GCT GAA
5222  K  E  L  K  K  I  I  G  Q  V  R  D  Q  A  E   pHDMHgpm2.seq
5222 AAG GAG CTG AAG AAG ATC ATC GGC CAA GTC CGC GAC CAG GCC GAG

                          4760
4742  H  L  K  T  A  V  Q  M  A  V  F  I  H  N  F   NL4-3 genbank.SEQ
4742 CAT CTT AAG ACA GCA GTA CAA ATG GCA GTA TTC ATC CAC AAT TTT
4740  H  L  K  T  A  V  Q  M  A  V  F  I  H  N  F   pNL4-3.seq
4740 CAT CTT AAG ACA GCA GTA CAA ATG GCA GTA TTC ATC CAC AAT TTT
5267  H  L  K  T  A  V  Q  M  A  V  F  I  H  N  F   pHDMHgpm2.seq
5267 CAC CTG AAG ACC GCC GTG CAG ATG GCC GTG TTC ATC CAC AAC TTC
```

Fig. 9J

Alignment Report of Codon Optimization (pol).MEG, using Clustal method with PAM250 residue weight table.

```
                4790                                                4820
4787  K  R  K  G  G  I  G  G  Y  S  A  G  E  R  I   NL4-3 genbank.SEQ
4787  AAA AGA AAA GGG GGG ATT GGG GGG TAC AGT GCA GGG GAA AGA ATA
4785  K  R  K  G  G  I  G  G  Y  S  A  G  E  R  I   pNL4-3.seq
4785  AAA AGA AAA GGG GGG ATT GGG GGG TAC AGT GCA GGG GAA AGA ATA
5312  K  R  K  G  G  I  G  G  Y  S  A  G  E  R  I   pHDMHgpm2.seq
5312  AAG CGC AAG GGC GGC ATC GGC GGC TAC TCC GCC GGC GAG CGC ATC

                          4850
4832  V  D  I  I  A  T  D  I  Q  T  K  E  L  Q  K   NL4-3 genbank.SEQ
4832  GTA GAC ATA ATA GCA ACA GAC ATA CAA ACT AAA GAA TTA CAA AAA
4830  V  D  I  I  A  T  D  I  Q  T  K  E  L  Q  K   pNL4-3.seq
4830  GTA GAC ATA ATA GCA ACA GAC ATA CAA ACT AAA GAA TTA CAA AAA
5357  V  D  I  I  A  T  D  I  Q  T  K  E  L  Q  K   pHDMHgpm2.seq
5357  GTG GAC ATC ATC GCC ACC GAC ATC CAG ACC AAG GAG CTG CAG AAG

          4880                                                4910
4877  Q  I  T  K  I  Q  N  F  R  V  Y  Y  R  D  S   NL4-3 genbank.SEQ
4877  CAA ATT ACA AAA ATT CAA AAT TTT CGG GTT TAT TAC AGG GAC AGC
4875  Q  I  T  K  I  Q  N  F  R  V  Y  Y  R  D  S   pNL4-3.seq
4875  CAA ATT ACA AAA ATT CAA AAT TTT CGG GTT TAT TAC AGG GAC AGC
5402  Q  I  T  K  I  Q  N  F  R  V  Y  Y  R  D  S   pHDMHgpm2.seq
5402  CAG ATC ACC AAG ATC CAG AAC TTC CGC GTG TAC TAC CGC GAC TCC

                          4940
4922  R  D  P  V  W  K  G  P  A  K  L  L  W  K  G   NL4-3 genbank.SEQ
4922  AGA GAT CCA GTT TGG AAA GGA CCA GCA AAG CTC CTC TGG AAA GGT
4920  R  D  P  V  W  K  G  P  A  K  L  L  W  K  G   pNL4-3.seq
4920  AGA GAT CCA GTT TGG AAA GGA CCA GCA AAG CTC CTC TGG AAA GGT
5447  R  D  P  V  W  K  G  P  A  K  L  L  W  K  G   pHDMHgpm2.seq
5447  CGC GAC CCC GTG TGG AAG GGC CCC GCC AAG CTG CTG TGG AAG GGC

          4970                                                5000
4967  E  G  A  V  V  I  Q  D  N  S  D  I  K  V  V   NL4-3 genbank.SEQ
4967  GAA GGG GCA GTA GTA ATA CAA GAT AAT AGT GAC ATA AAA GTA GTG
4965  E  G  A  V  V  I  Q  D  N  S  D  I  K  V  V   pNL4-3.seq
4965  GAA GGG GCA GTA GTA ATA CAA GAT AAT AGT GAC ATA AAA GTA GTG
5492  E  G  A  V  V  I  Q  D  N  S  D  I  K  V  V   pHDMHgpm2.seq
5492  GAG GGC GCC GTG GTG ATC CAG GAC AAC TCC GAC ATC AAG GTG GTG

                          5030
5012  P  R  R  K  A  K  I  I  R  D  Y  G  K  Q  M   NL4-3 genbank.SEQ
5012  CCA AGA AGA AAA GCA AAG ATC ATC AGG GAT TAT GGA AAA CAG ATG
5010  P  R  R  K  A  K  I  I  R  D  Y  G  K  Q  M   pNL4-3.seq
5010  CCA AGA AGA AAA GCA AAG ATC ATC AGG GAT TAT GGA AAA CAG ATG
5537  P  R  R  K  A  K  I  I  R  D  Y  G  K  Q  M   pHDMHgpm2.seq
5537  CCC CGC CGC AAG GCC AAG ATC ATC CGC GAC TAC GGC AAG CAG ATG
```

Fig. 9K

Alignment Report of Codon Optimization (pol).MEG, using Clustal method with PAM250 residue weight table.

```
                5060                                5090
5057  A  G  D  D  C  V  A  S  R  Q  D  E  D  -
5057  GCA GGT GAT GAT TGT GTG GCA AGT AGA CAG GAT GAG GAT TAA
5055  A  G  D  D  C  V  A  S  R  Q  D  E  D  -
5055  GCA GGT GAT GAT TGT GTG GCA AGT AGA CAG GAT GAG GAT TAA
5582  A  G  D  D  C  V  A  S  R  Q  D  E  D  -
5582  GCC GGC GAC GAC TGC GTG GCC TCC CGC CAG GAC GAG GAC TAA
```

NL4-3 genbank.SEQ

pNL4-3.seq

pHDMHgpm2.seq

Fig. 9L

```
AGCTTGGCCC ATTGCATACG TTGTATCCAT ATCATAATAT GTACATTTAT ATTGGCTCAT  60
GTCCAACATT ACCGCCATGT TGACATTGAT TATTGACTAG TTATTAATAG TAATCAATTA 120
CGGGGTCATT AGTTCATAGC CCATATATGG AGTTCCGCGT TACATAACTT ACGGTAAATG 180
GCCCGCCTGG CTGACCGCCC AACGACCCCC GCCCATTGAC GTCAATAATG ACGTATGTTC 240
CCATAGTAAC GCCAATAGGG ACTTTCCATT GACGTCAATG GGTGGAGTAT TTACGGTAAA 300
CTGCCCACTT GGCAGTACAT CAAGTGTATC ATATGCCAAG TACGCCCCCT ATTGACGTCA 360
ATGACGGTAA ATGGCCCGCC TGGCATTATG CCCAGTACAT GACCTTATGG GACTTTCCTA 420
CTTGGCAGTA CATCTACGTA TTAGTCATCG CTATTACCAT GGTGATGCGG TTTTGGCAGT 480
ACATCAATGG GCGTGGATAG CGGTTTGACT CACGGGGATT TCCAAGTCTC CACCCCATTG 540
ACGTCAATGG GAGTTTGTTT TGGCACCAAA ATCAACGGGA CTTTCCAAAA TGTCGTAACA 600
ACTCCGCCCC ATTGACGCAA ATGGGCGGTA GGCGTGTACG GTGGGAGGTC TATATAAGCA 660
GAGCTCGTTT AGTGAACCGT CAGATCGCCT GGAGACGCCA TCCACGCTGT TTTGACCTCC 720
ATAGAAGACA CCGGGACCGA TCCAGCCTCC CCTCGAAGCT GATCCTGAGA ACTTCAGGGT 780
GAGTCTATGG GACCCTTGAT GTTTTCTTTC CCCTTCTTTT CTATGGTTAA GTTCATGTCA 840
TAGGAAGGGG AGAAGTAACA GGGTACACAT ATTGACCAAA TCAGGGTAAT TTTGCATTTG 900
TAATTTTAAA AAATGCTTTC TTCTTTTAAT ATACTTTTTT GTTTATCTTA TTTCTAATAC 960
TTTCCCTAAT CTCTTTCTTT CAGGGCAATA ATGATACAAT GTATCATGCC TCTTTGCACC 1020
ATTCTAAAGA ATAACAGTGA TAATTTCTGG GTTAAGGCAA TAGCAATATT TCTGCATATA 1080
AATATTTCTG CATATAAATT GTAACTGATG TAAGAGGTTT CATATTGCTA ATAGCAGCTA 1140
CAATCCAGCT ACCATTCTGC TTTTATTTTA TGGTTGGGAT AAGGCTGGAT TATTCTGAGT 1200
CCAAGCTAGG CCCTTTTGCT AATCATGTTC ATACCTCTTA TCTTCCTCCC ACAGCTCCTG 1260
GGCAACGTGC TGGTCTGTGT GCTGGCCCAT CACTTTGGCA AAGAATTCTA GACTGCCATG 1320
GGCGCCCGCG CCTCCGTGCT GTCCGGCGGC GAGCTGGACA AGTGGGAGAA GATCCGCCTG 1380
CGCCCCGGCG GCAAGAAGCA GTACAAGCTG AAGCACATCG TGTGGGCCTC CCGCGAGCTG 1440
GAGCGCTTCG CCGTGAACCC CGGCCTGCTG GAGACCTCCG AGGGCTGCCG CCAGATCCTG 1500
GGCCAGCTGC AGCCCTCCCT GCAAACCGGC TCCGAGGAGC TGCGCTCCCT GTACAACACC 1560
ATCGCCGTGC TGTACTGCGT GCACCAGCGC ATCGACGTGA AGGACACCAA GGAGGCCCTG 1620
GACAAGATCG AGGAGGAGCA GAACAAGTCC AAGAAGAAGG CCCAGCAGGC CGCCGCCGAC 1680
ACCGGCAACA ACTCCCAGGT GTCCCAGAAC TACCCCATCG TGCAGAACCT GCAGGGCCAG 1740
ATGGTGCACC AGGCCATCTC CCCCCGCACC CTGAACGCCT GGGTGAAGGT GGTGGAGGAG 1800
AAGGCCTTCT CCCCCGAAGT CATCCCCATG TTCTCCGCCC TGTCCGAGGG CGCCACCCCC 1860
CAGGACCTGA ACACCATGCT GAACACCGTG GGCGGCCACC AGGCCGCCAT GCAGATGCTG 1920
AAGGAGACCA TCAACGAGGA GGCCGCCGAG TGGGACCGCC TGCACCCCGT GCACGCCGGC 1980
CCCATCGCCC CCGGCCAGAT GCGCGAGCCC CGCGGCTCCG ACATCGCCGG CACCACCTCC 2040
ACCCTGCAAG AGCAGATCGG CTGGATGACC CACAACCCCC CCATCCCCGT GGGCGAGATC 2100
TACAAGCGCT GGATCATCCT GGGCCTGAAC AAGATCGTGC GCATGTACTC CCCCACCTCC 2160
ATCCTGGACA TCCGCCAGGG CCCCAAGGAG CCCTTCCGCG ACTACGTGGA CCGCTTCTAC 2220
AAGACCCTGC GCGCCGAGCA GGCCTCCCAG GAGGTAAAGA ACTGGATGAC CGAGACCCTG 2280
CTGGTGCAGA ACGCCAACCC CGACTGCAAG ACCATCCTGA AGGCCCTGGG CCCCGGCGCC 2340
ACCCTGGAGG AGATGATGAC CGCCTGCCAG GGCGTGGGCG GCCCCGGCCA CAAGGCCCGC 2400
GTGCTGGCCG AGGCCATGTC CCAAGTCACC AACCCCGCCA CCATCATGAT CCAGAAGGGC 2460
AACTTCCGCA ACCAGCGCAA GACCGTGAAG TGCTTCAACT GCGGCAAGGA GGGCCACATC 2520
GCCAAGAACT GCCGCGCCCC CCGCAAGAAG GGCTGCTGGA AGTGCGGCAA GGAGGGCCAC 2580
CAGATGAAAG ATTGTACTGA GAGACAGGCT AATTTTTTAG GGAAGATCTG GCCTTCCCAC 2640
AAGGGAAGGC CAGGGAATTT TCTTCAGAGC AGACCAGAGC CAACAGCCCC ACCAGAAGAG 2700
AGCTTCAGGT TTGGGGAAGA GACAACAACT CCCTCTCAGA AGCAGGAGCC GATAGACAAG 2760
GAACTGTATC CTTTAGCTTC CCTCAGATCA CTCTTTGGCA GCGACCCCTC GTCACAATAA 2820
```

Fig. 10A

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AGATCGGTGG CCAGCTGAAG GAGGCCCTGC TGGACACCGG CGCCGACGAC ACCGTGCTGG  2880
AGGAGATGAA CCTGCCCGGC CGCTGGAAGC CCAAGATGAT CGGCGGCATC GGCGGCTTCA  2940
TCAAAGTCCG CCAGTACGAC CAGATCCTGA TCGAGATCTG CGGCCACAAG GCCATCGGCA  3000
CCGTGCTGGT GGGCCCCACC CCCGTGAACA TCATCGGCCG CAACCTGCTG ACCCAGATCG  3060
GCTGCACCCT GAACTTCCCC ATCTCCCCCA TCGAGACCGT GCCCGTGAAG CTGAAGCCCG  3120
GCATGGACGG CCCCAAAGTC AAGCAGTGGC CCCTGACCGA GGAGAAGATC AAGGCCCTGG  3180
TGGAGATCTG CACCGAGATG GAGAAGGAGG GCAAGATCTC CAAGATCGGC CCCGAGAACC  3240
CCTACAACAC CCCCGTGTTC GCCATCAAGA AGAAGGACTC CACCAAGTGG CGCAAGCTGG  3300
TGGACTTCCG CGAGCTGAAC AAGCGCACCC AGGACTTCTG GGAGGTGCAG CTGGGCATCC  3360
CCCACCCCGC CGGCCTGAAG CAGAAGAAGT CCGTGACCGT GCTGGACGTG GGCGACGCCT  3420
ACTTCTCCGT GCCCCTGGAC AAGGACTTCC GCAAGTACAC CGCCTTCACC ATCCCCTCCA  3480
TCAACAACGA GACCCCCGGC ATCCGCTACC AGTACAACGT GCTGCCCCAG GGCTGGAAGG  3540
GCTCCCCCGC CATCTTCCAG TGCTCCATGA CCAAGATCCT GGAGCCCTTC CGCAAGCAGA  3600
ACCCCGACAT CGTGATCTAC CAGTACATGG ACGACCTGTA CGTGGGCTCC GACCTGGAGA  3660
TCGGCCAGCA CCGCACCAAG ATCGAGGAGC TGCGCCAGCA CCTGCTGCGC TGGGGCTTCA  3720
CCACCCCCGA CAAGAAGCAC CAGAAGGAGC CCCCCTTCCT GTGGATGGGC TACGAGCTGC  3780
ACCCCGACAA GTGGACCGTG CAGCCCATCG TGCTGCCCGA GAAGGACTCC TGGACCGTGA  3840
ACGACATCCA GAAGCTGGTG GGCAAGCTGA ACTGGGCCTC CCAGATCTAC GCCGGCATCA  3900
AAGTCCGCCA GCTGTGCAAG CTGCTGCGCG GCACCAAGGC CCTGACCGAG GTGGTGCCCC  3960
TGACCGAGGA GGCCGAGCTG GAGCTGGCCG AGAACCGCGA GATCCTGAAG GAGCCCGTGC  4020
ACGGCGTGTA CTACGACCCC TCCAAGGACC TGATCGCCGA GATCCAGAAG CAGGGCCAGG  4080
GCCAGTGGAC CTACCAGATC TACCAGGAGC CCTTCAAGAA CCTGAAGACC GGCAAATACG  4140
CCCGCATGAA GGGCGCCCAC ACCAACGACG TGAAGCAGCT GACCGAGGCC GTGCAGAAGA  4200
TCGCCACCGA GTCCATCGTG ATCTGGGGCA AGACTCCCAA GTTCAAGCTG CCCATCCAGA  4260
AGGAGACCTG GGAGGCCTGG TGGACCGAGT ACTGGCAGGC CACCTGGATC CCCGAGTGGG  4320
AGTTCGTGAA CACCCCCCCC CTGGTGAAGC TGTGGTACCA GCTGGAGAAG GAGCCCATCA  4380
TCGGCGCCGA GACCTTCTAC GTGGACGGCG CCGCCAACCG CGAGACCAAG CTGGGCAAGG  4440
CCGGCTACGT GACCGACCGC GGCCGCCAGA AGGTGGTGCC CCTGACCGAC ACCACCAACC  4500
AGAAGACCGA GCTGCAGGCC ATCCACCTGG CCCTGCAAGA CTCCGGCCTG GAGGTGAACA  4560
TCGTGACCGA CTCCCAGTAT GCATTGGGCA TCATCCAGGC CCAGCCCGAC AAGTCCGAGT  4620
CCGAGCTGGT GTCCCAGATC ATCGAGCAGC TGATCAAGAA GGAGAAGGTG TACCTGGCCT  4680
GGGTGCCCGC CCACAAGGGC ATCGGCGGCA ACGAGCAGGT GGACAAGCTG GTGTCCGCCG  4740
GCATCCGCAA GGTGCTGTTC CTGGACGGCA TCGACAAGGC CCAGGAGGAG CACGAGAAGT  4800
ACCACTCCAA CTGGCGCGCC ATGGCCTCCG ACTTCAACCT GCCCCCCGTG GTGGCCAAGG  4860
AGATCGTGGC CTCCTGCGAC AAGTGCCAGC TGAAGGGCGA GGCCATGCAC GGCCAGGTGG  4920
ACTGCTCCCC CGGCATCTGG CAGCTGGACT GCACCCACCT GGAGGGCAAG GTGATCCTGG  4980
TGGCCGTGCA CGTGGCCTCC GGCTACATCG AGGCCGAGGT GATCCCCGCC GAGACCGGCC  5040
AGGAGACCGC CTACTTCCTG CTGAAGCTGG CCGGCCGCTG GCCCGTGAAG ACCGTGCACA  5100
CCGACAACGG CTCCAACTTC ACCTCCACCA CCGTGAAGGC CGCCTGCTGG TGGGCCGGCA  5160
TCAAGCAGGA GTTCGGCATC CCCTACAACC CCCAGTCCCA GGGCGTGATC GAGTCCATGA  5220
ACAAGGAGCT GAAGAAGATC ATCGGCCAAG TCCGCGACCA GGCCGAGCAC CTGAAGACCG  5280
CCGTGCAGAT GGCCGTGTTC ATCCACAACT TCAAGCGCAA GGGCGGCATC GGCGGCTACT  5340
CCGCCGGCGA GCGCATCGTG GACATCATCG CCACCGACAT CCAGACCAAG GAGCTGCAGA  5400
AGCAGATCAC CAAGATCCAG AACTTCCGCG TGTACTACCG CGACTCCCGC GACCCCGTGT  5460
GGAAGGGCCC CGCCAAGCTG CTGTGGAAGG GCGAGGGCGC CGTGGTGATC CAGGACAACT  5520
CCGACATCAA GGTGGTGCCC CGCCGCAAGG CCAAGATCAT CCGCGACTAC GGCAAGCAGA  5580
TGGCCGGCGA CGACTGCGTG GCCTCCCGCC AGGACGAGGA CTAACACATG GAAAAGATTA  5640
```

Fig. 10B

GTAAAACACC ATAGGCCGCT CTAGAGGATC CAAGCTTATC GATACCGTCG ACCTCGAGGG 5700
CCCAGATCTA ATTCACCCCA CCAGTGCAGG CTGCCTATCA GAAAGTGGTG GCTGGTGTGG 5760
CTAATGCCCT GGCCCACAAG TATCACTAAG CTCGCTTTCT TGCTGTCCAA TTTCTATTAA 5820
AGGTTCCTTT GTTCCCTAAG TCCAACTACT AAACTGGGGG ATATTATGAA GGGCCTTGAG 5880
CATCTGGATT CTGCCTAATA AAAAACATTT ATTTTCATTG CAATGATGTA TTTAAATTAT 5940
TTCTGAATAT TTTACTAAAA AGGGAATGTG GGAGGTCAGT GCATTTAAAA CATAAAGAAA 6000
TGAAGAGCTA GTTCAAACCT TGGGAAAATA CACTATATCT TAAACTCCAT GAAAGAAGGT 6060
GAGGCTGCAA ACAGCTAATG CACATTGGCA ACAGCCCCTG ATGCCTATGC CTTATTCATC 6120
CCTCAGAAAA GGATTCAAGT AGAGGCTTGA TTTGGAGGTT AAAGTTTTGC TATGCTGTAT 6180
TTTACATTAC TTATTGTTTT AGCTGTCCTC ATGAATGTCT TTTCACTACC CATTTGCTTA 6240
TCCTGCATCT CTCAGCCTTG ACTCCACTCA GTTCTCTTGC TTAGAGATAC CACCTTTCCC 6300
CTGAAGTGTT CCTTCCATGT TTTACGGCGA GATGGTTTCT CCTCGCCTGG CCACTCAGCC 6360
TTAGTTGTCT CTGTTGTCTT ATAGAGGTCT ACTTGAAGAA GGAAAAACAG GGGGCATGGT 6420
TTGACTGTCC TGTGAGCCCT TCTTCCCTGC CTCCCCCACT CACAGTGACC CGGAATCCCT 6480
CGACATGGCA GTCTAGATCA TTCTTGAAGA CGAAAGGGCC TCGTGATACG CCTATTTTTA 6540
TAGGTTAATG TCATGATAAT AATGGTTTCT TAGACGTCAG GTGGCACTTT TCGGGGAAAT 6600
GTGCGCGGAA CCCCTATTTG TTTATTTTTC TAAATACATT CAAATATGTA TCCGCTCATG 6660
AGACAATAAC CCTGATAAAT GCTTCAATAA TATTGAAAAA GGAAGAGTAT GAGTATTCAA 6720
CATTTCCGTG TCGCCCTTAT TCCCTTTTTT GCGGCATTTT GCCTTCCTGT TTTTGCTCAC 6780
CCAGAAACGC TGGTGAAAGT AAAAGATGCT GAAGATCAGT TGGGTGCACG AGTGGGTTAC 6840
ATCGAACTGG ATCTCAACAG CGGTAAGATC CTTGAGAGTT TTCGCCCCGA AGAACGTTTT 6900
CCAATGATGA GCACTTTTAA AGTTCTGCTA TGTGGCGCGG TATTATCCCG TATTGACGCC 6960
GGGCAAGAGC AACTCGGTCG CCGCATACAC TATTCTCAGA ATGACTTGGT TGAGTACTCA 7020
CCAGTCACAG AAAAGCATCT TACGGATGGC ATGACAGTAA GAGAATTATG CAGTGCTGCC 7080
ATAACCATGA GTGATAACAC TGCGGCCAAC TTACTTCTGA CAACGATCGG AGGACCGAAG 7140
GAGCTAACCG CTTTTTTGCA CAACATGGGG GATCATGTAA CTCGCCTTGA TCGTTGGGAA 7200
CCGGAGCTGA ATGAAGCCAT ACCAAACGAC GAGCGTGACA CCACGATGCC TGTAGCAATG 7260
GCAACAACGT TGCGCAAACT ATTAACTGGC GAACTACTTA CTCTAGCTTC CCGGCAACAA 7320
TTAATAGACT GGATGGAGGC GGATAAAGTT GCAGGACCAC TTCTGCGCTC GGCCCTTCCG 7380
GCTGGCTGGT TTATTGCTGA TAAATCTGGA GCCGGTGAGC GTGGGTCTCG CGGTATCATT 7440
GCAGCACTGG GGCCAGATGG TAAGCCCTCC CGTATCGTAG TTATCTACAC GACGGGGAGT 7500
CAGGCAACTA TGGATGAACG AAATAGACAG ATCGCTGAGA TAGGTGCCTC ACTGATTAAG 7560
CATTGGTAAC TGTCAGACCA AGTTTACTCA TATATACTTT AGATTGATTT AAAACTTCAT 7620
TTTTAATTTA AAAGGATCTA GGTGAAGATC CTTTTTGATA ATCTCATGAC CAAAATCCCT 7680
TAACGTGAGT TTTCGTTCCA CTGAGCGTCA GACCCCGTAG AAAAGATCAA AGGATCTTCT 7740
TGAGATCCTT TTTTTCTGCG CGTAATCTGC TGCTTGCAAA CAAAAAAACC ACCGCTACCA 7800
GCGGTGGTTT GTTTGCCGGA TCAAGAGCTA CCAACTCTTT TTCCGAAGGT AACTGGCTTC 7860
AGCAGAGCGC AGATACCAAA TACTGTTCTT CTAGTGTAGC CGTAGTTAGG CCACCACTTC 7920
AAGAACTCTG TAGCACCGCC TACATACCTC GCTCTGCTAA TCCTGTTACC AGTGGCTGCT 7980
GCCAGTGGCG ATAAGTCGTG TCTTACCGGG TTGGACTCAA GACGATAGTT ACCGGATAAG 8040
GCGCAGCGGT CGGGCTGAAC GGGGGGTTCG TGCACACAGC CCAGCTTGGA GCGAACGACC 8100
TACACCGAAC TGAGATACCT ACAGCGTGAG CTATGAGAAA GCGCCACGCT TCCCGAAGGG 8160
AGAAAGGCGG ACAGGTATCC GGTAAGCGGC AGGGTCGGAA CAGGAGAGCG CACGAGGGAG 8220
CTTCCAGGGG GAAACGCCTG GTATCTTTAT AGTCCTGTCG GGTTTCGCCA CCTCTGACTT 8280
GAGCGTCGAT TTTTGTGATG CTCGTCAGGG GGGCGGAGCC TATGGAAAAA CGCCAGCAAC 8340
GGATGCGCCG CGTGCGGCTG CTGGAGATGG CGGACGCGAT GGATATGTTC TGCCAAGGGT 8400
TGGTTTGCGC ATTCACAGTT CTCCGCAAGA ATTGATTGGC TCCAATTCTT GGAGTGGTGA 8460

Fig. 10C

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ATCCGTTAGC GAGGTGCCGC CGGCTTCCAT TCAGGTCGAG GTGGCCCGGC TCCATGCACC  8520
GCGACGCAAC GCGGGGAGGC AGACAAGGTA TAGGGCGGCG CCTACAATCC ATGCCAACCC  8580
GTTCCATGTG CTCGCCGAGG CGGCATAAAT CCCCGTGACG ATCAGCGGTC CAATGATCGA  8640
AGTTAGGCTG GTAAGAGCCG CGAGCGATCC TTGAAGCTGT CCCTGATGGT CGTCATCTAC  8700
CTGCCTGGAC AGCATGGCCT GCAACGCGGG CATCCCGATG CCGCCGGAAG CGAGAAGAAT  8760
CATAATGGGG AAGGCCATCC AGCCTCGCGT CGGGGAGCTT TTTGCAAAAG CCTAGGCCTC  8820
CAAAAAAGCC TCCTCACTAC TTCTGGAATA GCTCAGAGGC CGAGGCGGCC TCGGCCTCTG  8880
CATAAATAAA AAAAATTAGT CAGCCATG  8908
```

Fig. 10D

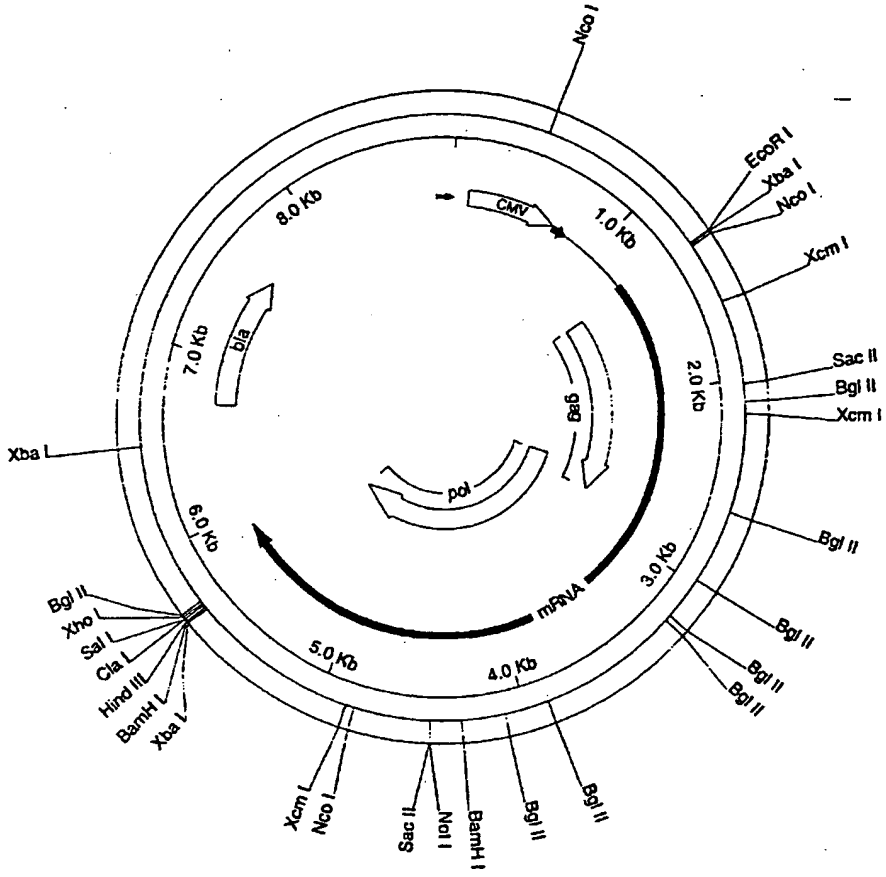
Nco I
EcoRI
Xba I
Nco I
Xcm I
Sac II
Bgl II
Xcm I
Bgl II
Bgl II
Bgl II
Bgl II
Bgl II
Bgl II
Xcm I
Nco I
Sac II
Not I
BamH I
Xba I
BamH I
Hind III
Cla I
Sal I
Xho I
Bgl II
CMV
1.0 Kb
2.0 Kb
3.0 Kb
4.0 Kb
5.0 Kb
6.0 Kb
7.0 Kb
8.0 Kb
bla
gag
pol
mRNA

Fig. 11

INTERNATIONAL SEARCH REPORT

National Application No
PCT/US 99/20675

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C12N15/86 C12N5/10 C12N7/04 C12N15/49 C07K14/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 C12N C07K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	NALDINI L ET AL: "IN VIVO GENE DELIVERY AND STABLE TRANSDUCTION OF NONDIVIDING CELLS BY A LENTIVIRAL VECTOR" SCIENCE,US,AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE,, vol. 272, no. 5259, 12 April 1996 (1996-04-12), pages 263-267, XP000583652 ISSN: 0036-8075 cited in the application the whole document --- -/—	1-4

[X] Further documents are listed in the continuation of box C. [ ] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 February 2000	03/03/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Chambonnet, F

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INTERNATIONAL SEARCH REPORT

national Application No
PCT/US 99/20675

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	HASELHORST D ET AL: "STABLE PACKAGING CELL LINES AND HIV-1 BASED RETROVIRAL VECTOR SYSTEMS" GENE THERAPY,GB,MACMILLAN PRESS LTD., BASINGSTOKE, vol. 1, no. SUPPL. 02, 18 November 1994 (1994-11-18), page S14 XP002063698 ISSN: 0969-7128 the whole document	—
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X	HOLLER T P ET AL: "HIV1 INTEGRASE EXPRESSED IN ESCHERICHIA COLI FROM A SYNTHETIC GENE" GENE,NL,ELSEVIER BIOMEDICAL PRESS. AMSTERDAM, vol. 136, 22 December 1993 (1993-12-22), pages 323-328, XP000199775 ISSN: 0378-1119 the whole document	39
A	ANDRE S ET AL: "INCREASED IMMUNE RESPONSE ELICITED BY DNA VACCINATION WITH A SYNTHETIC GP120 SEQUENCE WITH OPTIMIZED CODON USAGE" JOURNAL OF VIROLOGY,US,THE AMERICAN SOCIETY FOR MICROBIOLOGY, vol. 72, no. 2, 1 February 1998 (1998-02-01), pages 1497-1503, XP002073767 ISSN: 0022-538X the whole document	39-43

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